

Vehicle Refueling Emissions Seminar
Held at the Sheraton-Anaheim
Motor Hotel on December 4-5, 1973

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16. ABSTRACT This seminar focuses on the overriding regulatory aspects of refueling vapor control in response to the Clean Air Act. There are discussions on the current status on research and control technology of refueling emissions, the implementation capabilities, both present and future, the recovery equipment available, and the future outlook. There is an overview of the consideration of controls. Photographs and charts included.					
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**Sheraton-Anaheim Motor Hotel
Anaheim, California**

December 4-5, 1973



SPONSORS:

**American Petroleum Institute
California Air Resources Board
Environmental Protection Agency
Los Angeles Air Pollution Control District
Orange County Air Pollution Control District
Petroleum Equipment Institute
Western Oil and Gas Association**



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1801 K Street, N.W.
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EDITOR'S NOTE

In order to preserve the dynamics of the seminar, the text is based on a lightly edited transcript of the proceedings. In some instances, the prepared papers offer significant amplification of the remarks actually made at the seminar. Such papers, marked with an asterisk, appear in the Appendix as submitted. The affiliation of each participant is given only the first time his name appears, not thereafter.

TUESDAY MORNING SESSION

OPENING REMARKS

by
Carleton B. Scott

I would like to extend a most cordial welcome to all of you from the many sponsors of this Seminar: The American Petroleum Institute, California Air Resources Board, Environmental Protection Agency, Los Angeles APCD, the Orange County APCD, the Petroleum Equipment Institute, and the Western Oil and Gas Association.

I think it is appropriate, since this is the first time we've tried such a gathering on such a subject, to ask ourselves why we are here and what we hope to do. All of us are acutely aware that the regulations on refueling vapor recovery are coming thick and fast. Some of these regulations result from provisions of the Clean Air Act, some from concern at local levels. Some of them have compliance dates as far ahead as 1977; others must be met within the next thirty days. It is very easy to become confused as to who is doing what to whom, where we go from here, and how we are going to get there.

In view of the fact that many of the participants and others here have been working on this problem—in some cases for well over three years—and have gained a wealth of information and background on this entire subject, it seemed appropriate that we should get together to see whether we could sort out some pieces, get a clearer view of where we are headed. With this thought in mind, I have jotted down a few of the questions I think we are here to try to answer.

First, I think we need to ask: What are the overriding regulatory aspects of refueling vapor control and can we find some basic regulatory factors to guide us as we continue to strive for compliance? Second, what sort of progress are we making? Where do we stand at both the research level and the development level? What sort of hardware will we be looking at? Third, what are we doing about safety, and what are we going to do about safety? Is there any possible chance that we could injure customers or service station attendants? Fourth, what are we doing about assuring customers that they are getting what they pay for? Will they get all of the gasoline the dispenser says they got, or will the vapor recovery device somehow take back something which the customer thinks he owns? Finally, for all our efforts, can we really meet the mandated deadlines and recovery efficiencies?

These are some of the questions I perceive in this affair. I think that our job is to try and find some answers. In looking at our list of speakers and panelists, I am completely convinced that we have here today the people who can answer some of these questions. The Program Chairman, Bob Coit of Shell, the other chairmen and their committeemen—all have done an outstanding job, in my estimation, of pulling together the right people for this subject. How we'll answer these questions really depends upon the skill of the session chairmen, the willingness of the speakers "to tell it like it is," and the motivation of the audience to ask very difficult and very penetrating questions.

I'm going to do everything I can to find the answers, and I encourage all of you to do the same. These questions need to be answered, and they need to be answered right away.

I would now like to introduce Mr. Donald Walters, who is the Chairman of this session. Mr. Walters currently is Senior Technical Advisor to the EPA Deputy Assistant Administrator who directs the Office of Air Quality Planning and Standards in Research Triangle Park, North Carolina. He is a registered professional engineer in California and a member of the Air Pollution Control Association.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you, Mr. Scott. You have raised a lot of questions. Insofar as EPA policies are concerned, I've brought a lot of answers with me. I have a dozen yeses, a handful of maybes, and a few nos.

Recent events have shown that some people blame the energy crisis on the environmentalists and others in the air pollution field and similar fields. In this particular area, energy people and environmentalists are on a convergent course, it seems to me. We do have some things in common. Right now, for example, it would seem that all of us want to gather in all of the useful hydrocarbons we can get. I know I do—to burn in the 400-cubic-inch engine which I just bought. Like everybody else, you see, I had no advance knowledge about the gasoline situation.

I think we are also allied, of course, in the sense that conservation has been for years the basis of hydrocarbon control in the petroleum industry. To give us an overview we have with us today Mr. Fred Winkler, who is also from the Environmental Protection Agency. He is a mechanical engineer in the Land Use Planning Branch, which provided the technical assistance and support to the EPA Regional Offices in developing the Transportation Plans. In these plans are found the regulations that have formed some of the impetus for the research and development we are going to hear about today and tomorrow.

OVERVIEW OF VEHICLE REFUELING EMISSIONS

by
Fred Winkler

Good morning all. First, let me briefly explain the development of our present air pollution legislation.

As you may know, the Clean Air Act was passed in 1963, and the amendments to that Act were passed in 1970. There were previous acts, beginning with the Federal Control Act of 1955. There is quite a background to the present legislation. Basically, the theme has been that the state and local governments would be responsible for the prevention and control of air pollution at its source.

The amendments of 1970 provided the newly established Environmental Protection Agency with increased responsibility for enforcing pollution controls, in addition to increased authority to be used if the states should fail to meet their control responsibilities. The amendments also provided that EPA, assisted by the states, would designate air quality control regions. These regions are the basic geographic units in which the control process takes place.

Regional boundaries are based on considerations of climate, meteorology, topography, urbanization, and other factors affecting air quality conditions in each area. A region can cover only part of one state or it can include portions of several states sharing a common air pollution problem. The country has been divided into 247 such regions.

EPA must develop air quality criteria for the major pollutants involved, such as particulate matter, sulfur oxides, carbon monoxide, and hydrocarbons. Hydrocarbons in combination with nitrogen oxides in sunlight form photochemical smog. The criteria, which are issued in Criteria Documents, give the levels at which these pollutants by themselves and in combination with other pollutants are known to have adverse effects on public health and welfare.

EPA must also set national ambient air quality standards. These standards represent the maximum level permitted for a given pollutant. There are two kinds of such standards—primary and secondary. Primary standards must be sufficiently stringent to protect the public health. Secondary standards must protect the public welfare.

The primary and secondary standards for carbon monoxide are 10 milligrams per cubic meter, or 9 parts per million over an 8-hour period of maximum concentration. The primary and secondary standards for hydrocarbons are 160 micrograms per cubic meter, .24 part per million, maximum 3-hour concentration. None of these standards is to be exceeded more than once a year.

Each state is to prepare and submit to EPA plans to meet and maintain the ambient air quality standards in each air quality region within its jurisdiction. On August 14, 1971, the Administrator published guidelines in the *Federal Register* titled, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans." The states held public hearings on these plans and submitted them to EPA by January, 1972.

The plans that were submitted dealt almost exclusively with controls for such stationary sources as power plants, cement plants, and acid plants. It was realized in many states that control of such stationary sources, even in addition to the Federal Motor Vehicle Control Program, would not be adequate to meet the national ambient air quality standards for carbon monoxide and hydrocarbons—pollutants that in most cases are emitted by transportation sources. Due to a lack of information concerning transportation control, the states were given an additional year in which to submit detailed transportation plans to EPA. These plans were submitted to EPA by October 15, 1973, and the final version of these plans appears in recently published *Federal Registers*.

In addition to the designation of air quality control regions, the development of air quality criteria, the setting of standards, and the preparation of implementation plans, the Act called for the development of standards of performance for stationary sources, special treatment for hazardous pollutants, the setting of emission standards for motor vehicles beginning with the model year 1975, the monitoring of pollutant emissions for public information, the enforcement of standards and implementation plans by EPA, and the right of any citizen to bring suit against any person or corporation alleged to be violating an emission standard. Citizens might also sue the administrator of EPA for failure to perform duty required of him by the Act.

Transportation control plans provide for reduction in carbon monoxide and hydrocarbon levels required beyond reductions realized by the Federal Motor Vehicle Emission Control Program and the stationary source regulations set forth in the previously

approved state implementation plans that were submitted in January of '72. These reductions are to be accomplished through the implementation of the transportation control measures shown in Figure One, which represents about one dozen different types of control measures—with gasoline limitations, of course, being a last resort.

Taking into account the severity of the pollution problem, the availability of control measures, the existing local activities and conditions, the state transportation plan, the public hearing comments, the disruptive impact of certain measures, and its own proposed pollutant control strategies, EPA chose control measures according to the following priorities: 1) Additional stationary source control; 2) Some reduction of vehicle miles traveled and/or limited inspection and maintenance of vehicles; 3) Additional reduction of vehicle miles traveled and/or vehicle retrofits; 4) Catalytic converter retrofits; and 5) If all these other measures do not meet the standards, gasoline supply limitations in 1977.

Controls meant to reduce hydrocarbon emissions must necessarily be imposed on a variety of stationary sources. EPA regulations have been patterned on general examples of emission limitations obtainable with reasonably available technology. In addition to more stringent controls on many organic solvents used as paint thinners and in dry cleaning, degreasing, printing, and other industrial processes, vapor recovery systems that prevent evaporation of gasoline vapors into the atmosphere will be required for the various phases of gasoline marketing.

The implementation of vapor recovery systems depends on whether the controls are placed on the filling of service station tanks, stage one as we call it, or in the filling of individual vehicle tanks, stage two, and whether the degree of control in stage two is 80% or 90%.

The Administrator concluded that in most regions of the country, the implementation of stage one, filling of the underground service tanks, could be completed by March 1, 1976, assuming that adequate regulatory authority is available by March of 1974. If the stage two measure requires 80% control, its implementation can be completed by June of 1976. If the stage two measure requires 90% control, its implementation generally cannot be completed until May of 1977, due to greater technical problems. In a few regions these timetables can be accelerated, particularly

Additional Stationary Source Controls

Filling Service Station Tanks
Filling Auto Tanks
Loading and Unloading Barges
Solvent and Degreasing Controls
Architectural Coating
Dry Cleaning

Inspection and Maintenance

Light Duty Vehicle
Heavy Duty Vehicle

Traffic Flow/Transit

Improved Transit
Improved Traffic Flow
Bus/Carpool Lanes
Carpool Matching System
Transportation By-Pass

Traffic Disincentives

Parking Restrictions
Parking Surcharge
Bridge Tolls
Vehicle Free Zones
Delivery Bans
Idling Restrictions
Taxi Cruise Restrictions
Motorcycle Limits

Mechanical Retrofit

Vacuum Spark Advance Disconnect
Air Bleed
Catalyst
Truck Retrofit
High Altitude Modifications

Gasoline Limitations

FIGURE 1: Summary of Control Techniques.

State AQCR	Control Measure *	Completed By
CALIFORNIA		
Los Angeles	Stage I and II	1977
Sacramento	Stage I and II	1977
San Joaquin	Stage I and II	1977
COLORADO		
Denver	Stage I and II	1977
INDIANA		
Indianapolis	Stage I and II (Proposed)	1976
MASSACHUSETTS		
Boston	Stage I and II	1977
NATIONAL CAPITAL (D.C., VA., and MD.)	Stage I	1976
NEW JERSEY		
Newark	Stage I	1976
Philadelphia	Stage I and II	1977
PENNSYLVANIA		
Pittsburgh	Stage I	1976
TEXAS		
Austin-Waco	Stage I	1975
Houston-Galv.	Stage I and II	1977
Dallas-Ft. Worth	Stage I and II	1976
San Antonio	Stage I and II	1977
El Paso	Stage I and II	1975

* Stage I means controls placed on the filling of service station tanks. Stage II means controls placed on the filling of individual vehicle tanks.

See *Federal Register* (38 FR 30626) dated November 6, 1973, for a preamble on transportation controls and for sample regulations for the control of evaporative losses from the filling of storage vessels and vehicular tanks.

FIGURE 2: AQCR's Where Vapor Recovery Systems Are To Be Implemented.

where the number of service stations is not excessive. Figure Two indicates the air quality control regions where vapor recovery systems are to be implemented.

Note that there are some eight states, most of which require stage one and stage two—that is, controls on filling the underground tank and controls on filling automobile tanks. Most have until 1977 to meet the standard, but some must meet it as early as 1975.

There is a note at the bottom of Figure Two which I think very important, concerning information available in the *Federal Register*. For example, in the *Federal Register* dated November 6 there is quite an explanation of the transportation controls, including background information and some control measures which were considered. That particular issue also contains regulations for the State of Texas.

Although the hydrocarbon vapors emitted into the atmosphere from service stations cannot be considered as in-use vehicle exhaust emissions, the relationship between these vapor losses and the vehicle is so direct that their control can be thought of as a transportation control.

Service station vapor losses result primarily from tank truck unloading and vehicle fueling. The average service station pumps approximately 25,000 gallons of gasoline per month. In the process, it emits nearly 400 pounds of hydrocarbon vapor. By 1976

uncontrolled vapor losses of this magnitude will make the service station as important a source of hydrocarbon emissions as some of the vehicles it services. Translated into grams per mile, the hydrocarbon emissions from the service stations alone would exceed the 1976 new-car hydrocarbon emission standards.

Figure Three is a comparison of the cost-effectiveness of gasoline station controls, which appear quite high when compared to the

Control Measure	Cost Effectiveness *	Percent Reductions in Total Hydrocarbons **
I/M (all cars)	1.64	3.6
Catalyst ('72-'74)	1.79	1.31
Catalyst ('68-'74)	1.90	3.5
Air Bleed (pre-1968)	5.48	1.0
VSD (pre-1968)	6.91	1.2
Gasoline Station Controls	10.67 ***	7.1

* Pounds of pollutants controlled per dollar expended on the control device.

** Calculations based on a region with 30% stationary source HC contribution such as Philadelphia, Baltimore and Indianapolis.

*** Does not include control costs at loading rack.

FIGURE 3: Cost Effectiveness of HC Control Measures.

State (EPA Region) AQCR (City)	Reduction Required (%)		Inspection/ Maintenance	Catalytic Retrofit	Air Bleed Retrofit	VSD Retrofit	High Altitude Modifications	ECR/Air Steering	Gaseous Fuel	Traffic Flow Improvements	Parking Restrictions	Mass Transit Improvements	Additional Sta- tionary Source Controls	M/V Excl. Area	Bus/Carpool Lanes	Gasoline Limitations	Motorcycle Emission Regs.	Landing Limitations	Bicycle Lanes	Bus and Carpool Lanes	Mass Transit Incentives for Employees	Miscellaneous Measures	Station Control (%)
	CO	Other																					
Alaska (X) Northern Alaska Intra- State Region (Fairbanks)	66	-	E	E	E			E	E	E				E				E					24(CO)
Arizona (IX) Phoenix-Tucson Intra- state (Phoenix-Tucson)	66	-	S/E	S/E	S/E			S/E	S/E		E				S/E							Employee Carpool Incentives	25(CO)
California (IX) San Francisco Bay Area	31	78	E	E		S				E	E		E/S		E	1977	E	E		E	E	**	25(CO)
California (IX) Metropolitan Los Angeles	78	87	E	E		S				E/S	E		E/S		E	1977	E	E		E	E	**	24(CO)
California (IX) San Diego	90	75	E	E		S				E/S	E		E/S		E	1977	E	E		E	E	**	24(CO)
California (IX) Sacramento Valley	59	67	E	E		E				E/S	E		E		E	1977	E	E		E	E		24(CO)
California (IX) San Joaquin Valley	40	67	E	E		E				E	E		E		E		E			E	E		24(CO)
California (IX) *** Southeastern Desert	25	--					***														***	***	24(CO)
Colorado (VIII) Metropolitan Denver	64	56	S		S	S			S	S	S	S	E			E				S			24(CO)
Dist. of Columbia (III) National Capital Interstate (D.C., VA, & Md)	55	60	S/E	E	Fleet	E					S/E	S/E	S/E		S				E	S/E		Parking (\$5) Sur- charge	24(CO)
Illinois (V) Metropolitan Chicago Interstate (Chicago)	51	--	E							E	E												0
Indiana (V) Metropolitan Indianapolis (EPA Proposal)	25	30	E			E					E		E		E					E	E		12(CO)
Maryland (III) Metropolitan Baltimore Intrastate (Baltimore)	57	62	E	E		E		E			E		E		E	E				E	E	NO. C.A.T. converter	24(CO)
Massachusetts (I) Metropolitan Boston Intrastate	59	68	E	E	E	E					E		E									**	24(CO)
Massachusetts (I) Hartford-New Haven- Springfield Interstate	57	16	E							E	E				E							**	0
Minnesota (V) Minneapolis-St. Paul	40	--							S	S	S												0
New Jersey (II) N.Y., N.J., Conn. Interstate (Newark)	47	40	E	E				E			E		E		E	E				E	E	Deliv. Prohib. (E)	14 (CO) 24 (CO)

* Percent Reduction = (Oxidant Reading - Oxidant Standard) / Oxidant Reading

** Pricing Policies (E)

*** Depends on Control for Los Angeles

** Airfuel Control Retrofit on LDV, HDV, and M/V

FIGURE 4: Summary of Transportation Control Plans, November 30, 1973 (Continued on next page.)

November 30, 1973

***** Aircraft controls

As can be seen in Figure Four, many types of control measures were adopted in order to try to meet the standards. In some areas a 75% or 80% reduction was required to meet the oxidant standard. Clearly, gasoline service station controls have an important part in the reduction of hydrocarbons, especially in view of the high cost-effectiveness involved.

INTRODUCTION BY THE SESSION CHAIRMAN

I've seen the evolution of the *Federal Register* preambles over the last year or two. They are becoming very useful now. They explain the logic involved. Whether you agree with the logic and the data, of course, is something else. But I do highly recommend careful reading of these preambles.

We have seen what has, to some degree, prompted the interest in controlling hydrocarbon vapors from both stationary and transportation sources. The cost-effectiveness figures are really outstanding according to that chart.

Now, we're going to cover the status of research on this subject. Talking about control at the vehicle will be Mr. Don Olson. Mr. Olson is now an engineering consultant to Olson Laboratories.

CONTROL OF REFUELING EMISSIONS WITH ACTIVATED CARBON CANNISTER ON VEHICLE*

by
Donel R. Olsen
John A. Gunderson
Don K. Lawrence

Thank you, Don. I am going to talk to you about the containment of vehicle refueling vapors with a carbon canister attached to the automobile. This includes the results of a project that we have recently completed, using one automobile and some very limited research work.

We all know that the automobile is one of the major sources of pollution. I don't think I have to belabor that point. Another source of vehicle emissions are the vapors that escape from the fuel tank at the time of refueling. The objective of our project was to determine the technical and economic feasibility of using a carbon canister—an activated carbon canister system—on automobiles to control those refueling vapor losses. As a secondary objective we were to determine the effects of this system on vehicle exhaust emissions, on evaporative emissions, and on vehicle driveability—all of which are important parameters in the design of an emission control system for the automobile.

Our technical approach was to design a prototype carbon canister system which would be capable of handling all the refueling vapors. We initially undertook these studies on a bench-test scale to define the total amount of refueling vapor to be handled, the vapor retention capacity of the carbon canisters, and the purge capacity over a range of operating conditions. The system was fabricated, installed on a test vehicle, and operated under simulated use conditions. We measured the amount of refueling control that we had of the vapors from the fuel tank. We measured the effect on exhaust emissions, using the federal test procedures, and the effect on driveability, using the California Air Resources Board driveability procedures.

We modified the system where necessary and then tried to optimize it. We then determined the effectiveness and cost of the system. The cost was determined as the incremental cost over and above those evaporative controls which would already be on vehicles over the time period of our study. Those manufacturing cost estimates were then used to make cost-effectiveness conclusions.

Looking at the parameters we were controlling for the refueling study, we arbitrarily selected three conditions—nominal, severe, and extreme. The facts used to quantify these conditions are listed in Figure One.

The ideal gas law was used to determine, at the beginning of the program, the amount of hydrocarbon emissions we would get from these three fuels. Looking at the nominal case, which is a nine-pound fuel, up to the extreme case, which is an eleven-and-a-half-pound fuel, as well as differences in fuel temperatures, we calculated that we could expect about 5.6 grams of hydrocarbon per gallon of refill for the nominal case, and nine grams of hydrocarbon vapor—per gallon of refill—under the extreme condition.

We then had to match these fuels with actual test fuels. We did so by selecting an unleaded, regular-grade fuel of about nine-pound

Description	Test Condition		
	Nominal A	Severe B	Extreme C
RVP, psi	9.0	10.5	11.5
Fuel dispensed, gallons	17.0	18.0	22.0
Tank fuel temperature, °F	95.0	95.0	112.0
Dispensed fuel temperature, °F	82.0	82.0	82.0
Calculated HC vapor emission, grams/gallon	5.6	6.4	9.0
Calculated HC vapor recoverable (grams)	95.0	115.0	198.0

FIGURE 1: Refueling Conditions.

Reid vapor pressure, along with another commercial fuel having a 12.1 pound Reid vapor pressure. We matched the severe and the nominal fuels with these test fuels. The nominal fuel was an Indolene 30 fuel, which was also used for the exhaust emission measurements.

I've just shown some of the summary information on the distillation characteristics, lead content, and vapor pressure of those fuels. We did not use any weathered fuel in the program. We drew enough sample to conduct a test series in a given period of time, and any unused fuel was disposed of. We used a fuel conditioner to control the temperature—that is, a fuel-conditioning cart to control the temperature of the test fuel for all of the bench testing and vehicle test work.

The test vehicle was a 1973 Ford Gran Torino with a 351-cubic-inch engine, a 2-Venturi carburetor, automatic transmission, air conditioning, power steering, and power brakes. This vehicle was selected because it seemed to be representative—as popular a model passenger vehicle as we could get compared with such other popular models as Chevrolet and Plymouth. Ford vents the carburetor internally, using a relatively smaller carbon canister as part of the existing evaporative emission control system and purging the canister into the air-cleaner element rather than into the intake manifold. These features of the system made it relatively simple for us to modify, using existing commercially available components.

Figure Two is a schematic of that Ford system. The fuel filler neck on the Ford was also accessible for modification so we could obtain nozzle sealing. The present 1973 Ford Gran Torino emission control system has a 50-thousandths-inch vapor separating orifice—shown here in an enlarged view. There is a quarter-inch line connected to a carbon canister containing about 700 grams of charcoal. It vents into the air cleaner element of the carburetor. That is the system we modified to collect the vapors lost during refueling. We used theoretical data to calculate what we thought the loss would be.

Figure Three shows the relationship between Reid vapor pressure and vapor temperature on the ordinate, and vapor emissions in grams per gallon on the abscissa. We determined from these theoretical calculations based upon the perfect gas law that we would need a capacity of about 198 grams for that charcoal canister during a refueling operation. The canister, under extreme conditions, would have to hold about 198 grams of hydrocarbons in addition to the load it would have from normal evaporative losses during diurnals and hot soaks.

Figure Four indicates the results of preliminary bench testing for those three fueling conditions. These are actual bench test results for the three fuels representing nominal, severe, and extreme cases. For the nominal and severe cases the hydrocarbon vapor in grams per gallon was about 5.1 and 5.4, respectively, following our predictions pretty accurately. The extreme fuel did not follow our predictions—the loss being only 2.9 grams per gallon. Although we did not explore this matter in depth, we determined to our own satisfaction that the reading was due to condensation occurring as a result of the tank fuel temperature being 112 degrees and the dispensed fuel being 82 degrees. We were getting some flash cooling and condensation of vapors. This extreme case, then, turns out to be not so extreme in terms of those conditions of temperature and volatility.

Figure Five is the schematic of the bench-test setup. We took a prototype canister with 2000 grams of carbon and did some

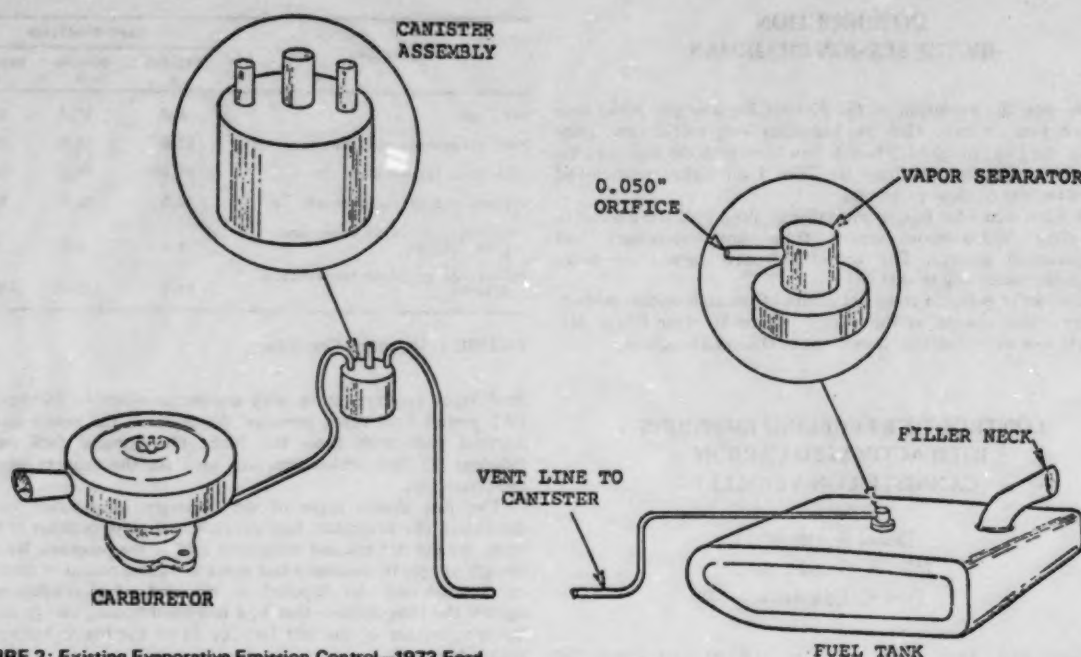


FIGURE 2: Existing Evaporative Emission Control—1973 Ford Gran Torino.

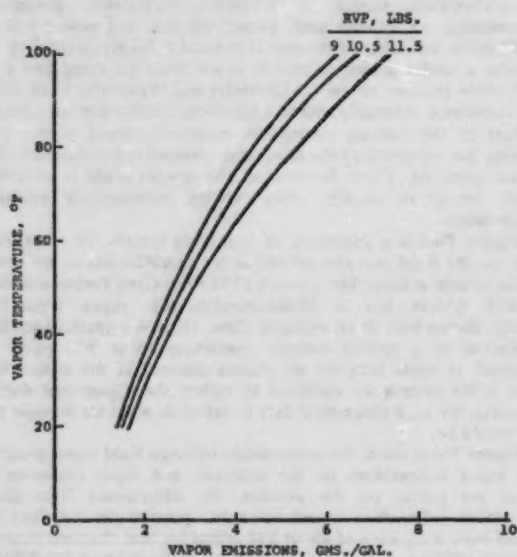


FIGURE 3: Influence of RVP and Temperature on Vapor Emissions During Refueling.

Characteristics	Refueling Conditions		
	Nominal	Severe	Extreme
RVP	9.2	10.8	11.5
Fuel dispensed, gallons	17.0	18.0	22.0
Tank fuel temperature, °F	95.0	95.0	112.0
Dispensed fuel temperature, °F	82.0	82.0	82.0
HC vapor to canister, grams	86.6	97.4	51.4
HC vapor, grams/gallon dispensed calculated average	5.1	5.4	2.9

FIGURE 4: Bench Test Results.

preliminary bench testing. We weighed the canister. This bench test apparatus was also used to condition the canister, to determine the amount of charging accomplished during normal diurnals, and to discover how much was retained in the charcoal canister. Our aim, of course, was to get a measure of carbon retention effectiveness.

We used a butane cylinder and pressurized the fuel tank under heated conditions to control the temperature, with a balance to weigh the canister. Then we used a balanced pressure apparatus (that's what the manometer is for), a fuel meter, and a Roots air pump to draw air through the carbon canister. We cycled that canister while continuing to charge and purge it to determine how much vapor retention it would stand under normal operating conditions. That was our bench test setup, and we did a lot of work with it.

In the light of our various bench test activities and some vehicle testing, we did size the system for the Ford Gran Torino.

Figure Six illustrates our findings. The standard system is in the first column. In the last column is the modification we made to that system. In order to eliminate large pressure build-ups in the tank, we replaced the 50-thousandths orifice with a 3/8-inch vapor-separating orifice. We then replaced the quarter-inch lines to the carbon canister with the 3/8-inch lines. Of course, we then had to replace the 700 gram canister with a 2000-gram canister. We had to have a tight seal at the fuel-filling nozzle, and so we used an elastometer diaphragm placed in the fuel tank fill-pipe. That provided a tight seal for our tests. Today I think we'll hear other methods of solving this problem.

Exhaust emissions, as I said, were measured by the CVS Federal Test Procedure, with a prototype canister installed.

In Figure Seven we see a comparison of results for the production model vehicle and a prototype vehicle equipped with the refueling controls. Incidentally, these are the averages of six tests in each case, and they represent significant differences for the carbon monoxide concentration. There is about a 10.8 grams-per-mile increase in carbon monoxide concentrations and about a .6 gram-per-mile decrease in nitrogen oxides. Both of these numbers are significant at about 95% probability. The difference in hydrocarbon was not significant, so there was no significant effect on hydrocarbons.

As I mentioned earlier, we also measured driveability with this system installed. Using the California Air Resources Board Procedure, we could not measure any significant different in driveability of the vehicle.

The effectiveness of a program to recover refueling vapor losses involving implementation of these systems on automobiles depends

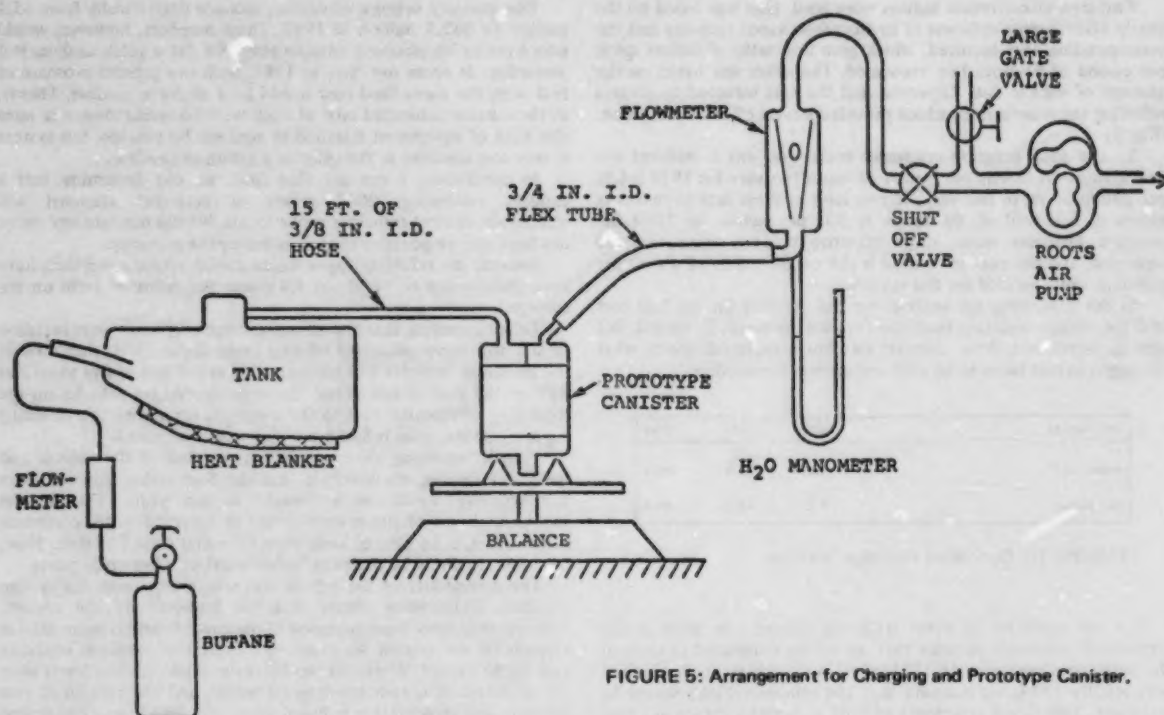


FIGURE 5: Arrangement for Charging and Prototype Canister.

Description	Present	Prototype
Carbon Canister	700 g	2000 g
Vapor Separator	0.050 in.	0.375 in.
Transfer Tubing	0.25 in.	0.375 in.

FIGURE 6: Changes In Standard System.

Description	HC	CO	NO _x
Production	3.3	40.9	3.7
Prototype	3.4	51.7	3.1

FIGURE 7: Exhaust Emissions In Grams per Mile.

on the yearly introduction of new control vehicles, on the attrition and salvage rate of the older uncontrolled vehicles, and on the relative amounts of fuel consumed by both controlled and uncontrolled vehicles.

Our study assumed implementation would begin with 1975 model vehicles. Our summary figures indicate, through 1984, the degree of control that can be expected. Implementation in 1975 would result in about 8.1% of the population of vehicles on the road having controls, and about 11.9% of the total fuel dispensed would be dispensed into these vehicles. This progresses, so that by 1984, 84% of the vehicles on the road would be controlled, and 91.7% of the total fuel dispensed would be dispensed under controlled conditions.

In developing the detailed cost analysis necessary to provide a framework for computing and evaluating the unit production cost

and the total program cost associated with each design, we had to make estimates of the effect of inflation on labor, material, and gasoline cost. The cost model also included the necessary factors to determine annualized cost.

This estimate was made about two or three months ago, so we are out of date on the cost of gasoline—by a considerable margin. Because I was sure that would be a question that you would ask, we used a 1975 gasoline cost of 46¢ a gallon. At one time along the line, we proposed a much larger figure—but everyone knew that gasoline couldn't possibly be 52¢ or 53¢ a gallon in 1975. In any event, we used 46¢ a gallon, and escalated that amount at 1½% per year so that by 1984 we had 52¢ a gallon. But, as I say, that's a long time ago.

The costs that I am going to be talking about are all incremental costs. They are not absolute costs. By incremental, I mean costs added to those of the equipment already on automobiles, beginning in 1975 and continuing through 1984. These costs are incremental to those of evaporative control systems that we foresee as being on automobiles as a result of present legislation.

Description	Nominal	Severe
Carbon canister, grams	1,760	2,000
Unit production cost	\$3.85	\$3.09
Unit consumer cost	\$4.48	\$4.85

FIGURE 8: Unit Costs.

Figure Eight includes unit costs for the nominal and severe cases. Looking at the severe case for a 2000-gram canister, we determined that the production cost—the incremental production cost—for that canister is \$3.09, resulting in a consumer cost of \$4.85.

Description	1975	1979	1984
Dollars/pound vapor recovered	0.89	0.14	0.13
Cents/gallon fuel refilled	0.83	0.19	0.14

FIGURE 9: Cost Indices.

Two cost effectiveness indices were used. One was based on the yearly effectiveness estimate of hydrocarbon vapor recovery and the corresponding cost incurred, which gave us a ratio of dollars spent per pound of hydrocarbon recovered. The other was based on the amount of vehicle fuel dispensed and the cost incurred to control refueling vapor emissions, which provided a ratio of cents per gallon. (Fig. 9)

So the total program consumer costs—and this is without the fuel savings—in dollars per pound of vapor recovery for 1975 is 69¢ per pound of vapor recovery. If you look at these data in cents per gallon of fuel refilled, the figure is .83¢ per gallon. By 1984 the program becomes much more effective because more cars are equipped, and the cost per gallon is .14 or 1½ tenths of a cent per gallon of vapor refilled for this system.

In the total program analysis we did account for the fuel cost and the savings resulting from the fuel that is saved. Of course, as I already mentioned, those costs are very low now, in relation to what we might expect them to be with our present knowledge.

Description	1975	1979	1984
Number (10 ⁶)	7.3	48.6	103.6
Percentage	8.1	47.2	84.2

FIGURE 10: Controlled Passenger Vehicles.

Let me move on to some statistics. Figure Ten includes the number of passenger vehicles that would be controlled in each of the corresponding years. In 1975, then, 8.1% represents 7.3 million vehicles. By 1984, we estimate that 104 million vehicles would be equipped. This figure represents 84% of all vehicles driven in 1984.

Description	1975	1979	1984
To controlled passenger vehicles (10 ⁹ gallons)	7.0	39.0	73.6
To all passenger vehicles (10 ⁹ gallons)	58.6	87.1	88.1

FIGURE 11: Fuel Dispensed.

Figure Eleven estimates the amount of fuel which would be dispensed in 1975 to that 8% of the cars, which represented 11.9% of the total fuel dispensed. Seven billion gallons would go into controlled vehicles, and into all passenger vehicles would go a total of 58.6 billion gallons. Again, this is old information. Perhaps today we may expect a little less than the 58.6 billion gallons estimated for 1975. In 1984, then, we would expect to have 73.6 billion gallons of the 80.1 billion total dispensed into controlled vehicles—if this program should be implemented in 1975.

Description	10 ⁹ Dollars		
	1975	1979	1984
Manufacturing	36.8	48.4	69.6
Consumer	57.8	76.8	109.3
Recovery Savings	5.4	31.4	61.5
Annualized Cost	48.3	48.5	48.5

FIGURE 12: Cost Increases.

Figure Twelve is a projected summary of the manufacturing and consumer costs. This shows recovery savings based upon the 46¢ a gallon figure in 1975, which escalates to 52¢ in 1984. The annualized cost, with this analysis, turns out to be essentially constant over the 10-year time frame that we analyzed. Manufacturing costs for '75 are \$36.8 million, and they escalate to \$69.6 million. This is the incremental absolute cost in each of these years—that is, the added cost over and above the evaporative emission control system that would already exist.

The recovery savings, of course, increase dramatically from \$5.4 million to \$63.5 million in 1984. These numbers, however, would now have to be escalated considerably. We did a quick analysis just yesterday. It turns out that in 1984, with our present estimate of fuel cost, the annualized cost would be a negative number. That is, at the current estimated cost of fuel, we'd be saving money to have this kind of equipment installed in vehicles. So you see, this system is very cost sensitive to the price of a gallon of gasoline.

In conclusion, I can say that first, we did determine that a canister containing 2000 grams of activated charcoal will effectively control refueling vapor losses. We did not lose any vapor nor have any evaporative emissions during the refueling.

Second, the refueling vapor losses during severe conditions have been determined to be about 5.4 grams per gallon of refill on the average.

Third, assuming that the refueling control systems were installed in new light-duty passenger vehicles beginning in 1975, then 47% of the passenger vehicles will be controlled at the end of five years and 84% at the end of ten years. Those are passenger vehicles on the road. The differential cost to the consumer for adding this refueling vapor control system is \$4.85 per manufactured vehicle.

Fourth, assuming an expected ten-year life of the vehicle and using our figures, we conclude that the fuel savings realized from this recovery would be a "wash" in ten years. That is, the incremental cost of the system would be returned to the consumer in ten years, if he were to keep his car for that period of time. Now, of course, it would be returned faster—maybe in five or six years.

The driveability of the vehicle was satisfactory with the system installed. Evaporative testing was not impaired by the system. Exhaust emissions were increased in the case of carbon monoxide as a result of the system we examined. Oxides of nitrogen levels, as you might expect, decreased significantly. Hydrocarbon levels were not affected. It is important to recognize, and I'm sure all of you do, that this presentation is based upon one vehicle and one design and is certainly preliminary in nature.

This pretty much summarizes the research effort that we have made toward controlling refueling losses at the vehicle with a carbon canister.

In closing, I want to mention John Gunderson of Olson Laboratories and Don Lawrence of Amoco, who worked as co-authors of this presentation. John Gunderson has just given me a note saying that the test vehicle is here. Don't expect too much—it's not very spectacular. Our work consists just of a modified filler neck and a larger carbon canister with even larger plumbing. At any rate, for those of you who are interested, tomorrow we'll just have it parked out in front—a red Ford Gran Torino.

Thank you very much.

INTRODUCTION BY THE SESSION CHAIRMAN

That was an excellent presentation, in spite of the fact it drove the panel members from the podium. But I don't think their leaving is your fault.

We'll next hear from Mr. Martens, who represents the General Motors Corporation, concerning the question of controlling automobile refueling emissions in California. Mr. Martens has Bachelor and Master Degrees in Engineering from the University of Arizona and Arizona State. He spent quite a few years with the GM Desert Proving Grounds in Phoenix and then presumably got unlucky. He moved East with General Motors and is now associated with the company's Automotive Emission Control Office, Environmental Activity Staff. He is a member of the Society of Automotive Engineers and American Society of Mechanical Engineers. He is a member of Tau Beta Pi, Phi Kappa Phi, and a registered Professional Engineer in Arizona. Mr. Martens.

AN AUTOMOBILE INDUSTRY VIEWPOINT (I)*

by
Stuart W. Martens

Thanks, Don. If I may for just a moment belabor the title of this discussion, you will note from the folder it's *An* Automotive Industry Viewpoint. I'd like to emphasize that word *an*. It's not *The* Automotive Industry Viewpoint. What I have to say is the opinion of General Motors Corporation exclusively.

I'd like first to talk in a few generalities, since we've heard a lot of specifics from Don Olson, on control technology. From the information available to General Motors it appears to us that the control technology that's being talked about for control of refueling emissions looks pretty good from the point of view of technical feasibility. The demonstration, however, we'd all have to concede is incomplete at this time. Effectiveness also looks pretty good, again from the information available to us.

It is our view, however, that from what we know and from what we've seen, control isn't 100% effective, if I may take mild issue with one of Don's comments. We think from what we've seen that maybe it's 90% effective. Even that we think is possibly a little shaky.

When we concede that we've got an emission problem here that is not inherently completely controlled by a hardware scheme, then we face the problem of deciding what the acceptable level of emission is, the definition of that acceptability level, and with it a test procedure. I think it's interesting that just within the last couple

of months we have on record from a recognized technical body a test procedure for measurement of automobile refueling emission. I think Paul Mutty probably will have a little more to say about that in a few minutes.

When we look at the refueling problem in the general context of emissions, either mobile sources or stationary sources, we've got a unique thing in that we're looking at the interface between stationary sources and mobile sources. Indeed, it's that interface itself that's causing the emission. So we have a unique situation here of a choice between control of that emission on either side of the interface—either at the service station or on board the using vehicle itself, as Don has just described.

When we look at service station control, a few things come to mind. Ideally, in our view again, control applies to— or could apply to— all cars, not just new cars, but used cars and transient vehicles as well. Very importantly, we think, the problem appears amenable to regionalized control. Certainly new equipment is required in the service station. Additionally, there's the well-recognized problem of the interface with the vehicle—that is, the very, very large number of configurations of vehicle fuel filler.

On the other hand, if we look at the on-board system which Don has described very well for us, the obvious approach is expansion and sophistication of the already existing evaporative emission control which is already on millions of our vehicles. As Don has indicated, we feel strongly that such an approach is applicable in new cars only. Moreover, it appears that some additional service station hardware will still be a necessity. Obviously, with vehicle evaporative control, it's much more difficult to regionalize, which again we think is an extremely important point.

Now, looking at these two alternatives I think probably it wouldn't be a surprise to anybody here what my choice of the point of control would be. I will say, however, that in our viewpoint it looks as though, from the standpoint of technical feasibility, the choice probably isn't completely clear-cut. On the other hand, if we look at social and economic costs, it does look like a pretty definitely clear-cut choice.

Mr. Winkler, I think, pointed out the fact that the control of hydrocarbon emissions is definitely a regionalized problem in this country. We've heard over the last year or two more and more questioning of the wisdom of applying extreme emission controls to every car in the nation to solve the most severe problem in a particular locale. I think as we look at this essentially new emission mode for control, it's important that we recognize the validity of that questioning.

This particular emission mode appears to be ideally suited to regionalized control with the service station approach. At least to us, it appears pretty obviously better to install service station

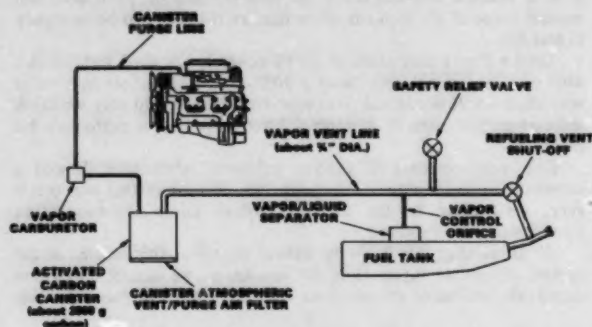


FIGURE 1: On-Board Refueling Emissions Control Schematic.

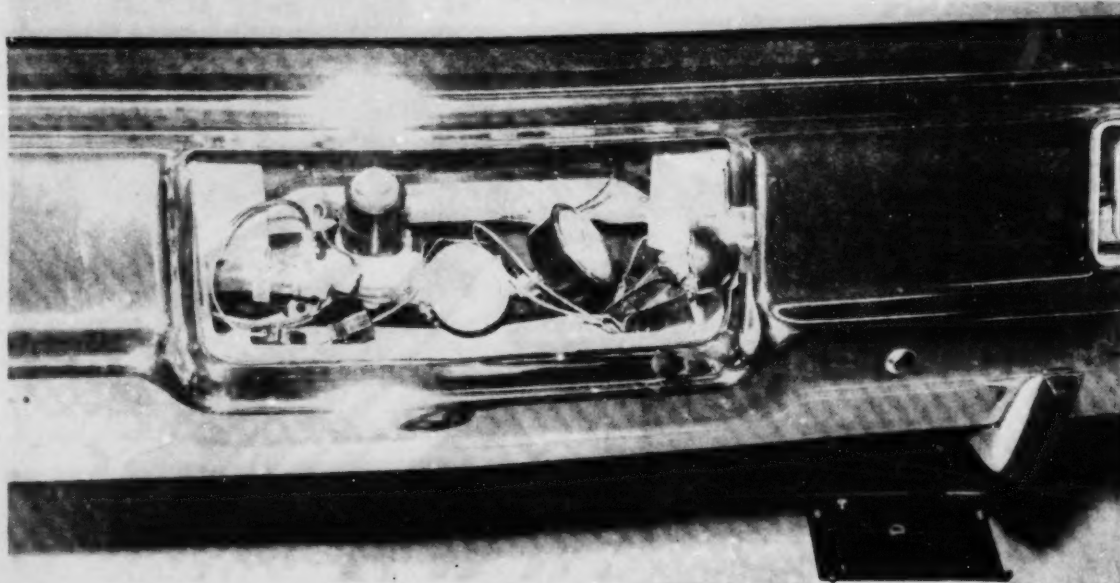


FIGURE 2: Venting Hardware for Experimental On-Board Refueling Emission Control System.

control equipment in every station in Los Angeles, San Diego, Houston, and some of these other cities that Mr. Winkler showed us one time, rather than to install hardware in every single new car in this country from some year X on into infinity.

I'd like quickly to show you some of the thoughts that General Motors has had on the subject and some of the things that we've done. To look at the on-board system first, as I say, Don has described that very well. There really are two concepts that we're aware of. One is a collapsible tank, which Don has not talked about. In our view, that is a concept only, very much as the carnot cycle is a heat engine concept. Nobody really has built an engine to operate in that cycle, but it is a well-established concept in the literature.

The carbon canister expansion that Don has talked about, however, does represent reality as well as concept. We've got millions of vehicles in the population right now operating with carbon canister controls for hydrocarbon vapors.

Figure One is a schematic of the kinds of elements that we think are necessary to build a realistic operable refueling emission control system on board a car. Don has already mentioned some of these. I think with some of his points we differ slightly. To accommodate the very high refueling flow rate, we indicate a very large pipe compared to the vent system that we have now. We see a need to close off that high-flow capacity vent, so the normal venting functions of vapor liquid separation and flow control for the evap system will not be impaired by this large flow capacity. A safety relief valve would be necessary to replace the one that we now have in the cap.

As Don has mentioned, the expansion of the carbon canister is necessary. We've indicated a total of 2500 grams, not terribly different from the figure that Don talked about. We've shown a necessity for a vapor carburetor, or if you will, a substantial increase in sophistication of the present purge system.

Figure Three proves that we were able to squeeze three additional canisters under the hood of the Chevrolet Impala. Here's an experimental expedient of an installation of a very high-flow capacity vent at the filler neck. Again, as an expedient, an electrical solenoid valve was used to shut the refueling vent off during normal vehicle operation. That's a rather interesting requirement I think. Figure Four shows a partial solution to that problem, if it were necessary actually to impose it. Here the large flow capacity vent from the filler neck tees into the normal vapor control system. In this case, however, instead of a valve, you see a double seat on the cap which would close off the high-flow capacity vent and allow venting of the tank only through the normal vapor control system.

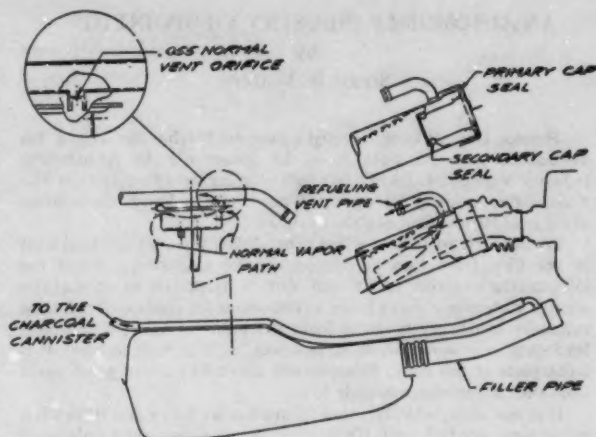


FIGURE 4: Fuel Tank Venting System.

We have made some experimental evaluations of a system of this type—a vehicle with the type of equipment that you have seen here. I want to emphasize that we are discussing a simple expansion of the production evaporative control system, as simple as we knew how to make it and still make the vehicle operable. So it does not include some of the sophistication that we think would be necessary in real life.

Unlike Don's indication of 100% control, our shed tests of this kind of a system showed about a 90% control. The fact that we're very close to 90% control gives you some insight into why we think indicating that sort of a control level as a goal is perhaps a bit marginal.

Our measurements of exhaust emission interaction showed a carbon monoxide increase of about 30%. It's interesting that this is very, very close to the exhaust carbon monoxide interaction numbers that Don showed.

We think that this is a very serious question—this matter of the carbon monoxide interaction. As you know, we cannot let carbon monoxide emissions go wherever they will. We therefore view this

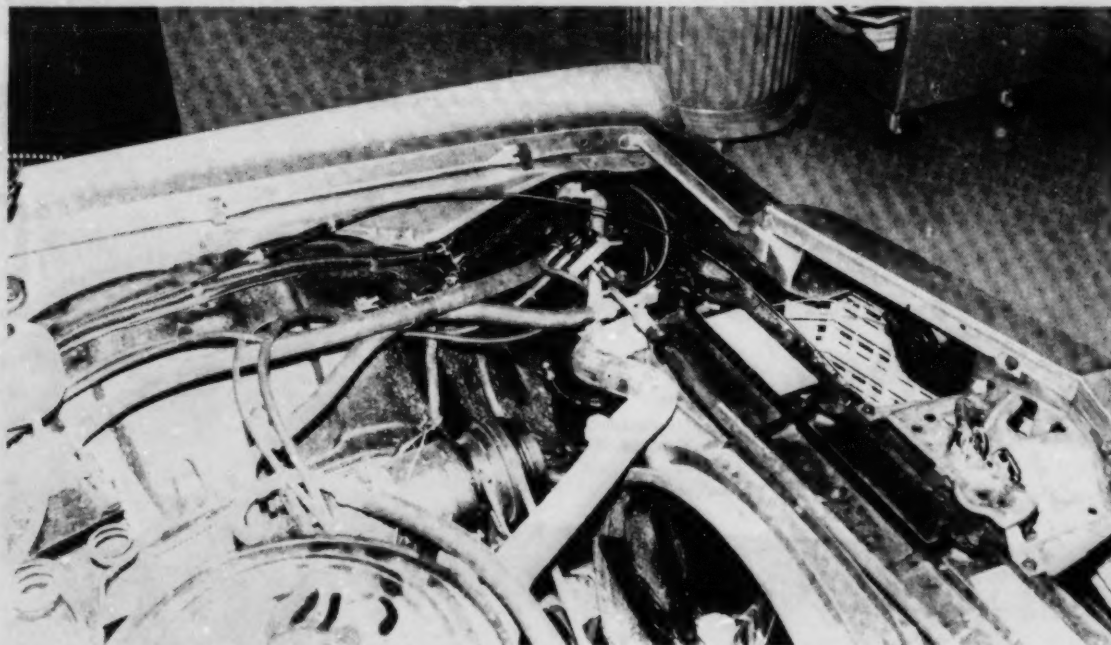


FIGURE 3: Charcoal Canister Installation for Experimental On-Board Refueling Emission Control System.

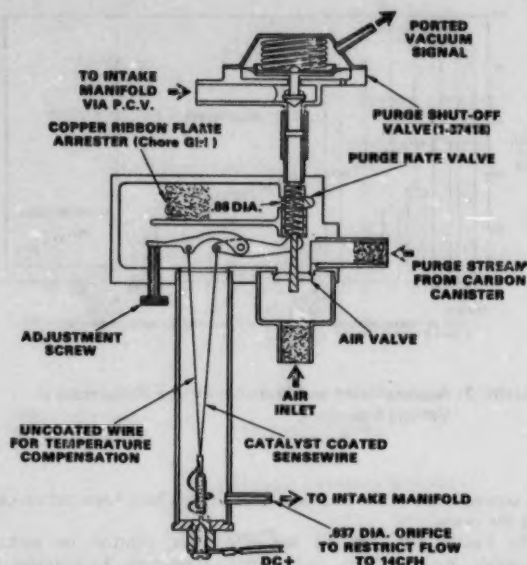


FIGURE 5: Purge Air-Fuel Ratio Controller.

problem as imposing a very serious additional requirement on an on-board refueling emission control system.

Figure Five shows a gadget that might be installed as a vapor carburetor to handle the interaction problem. It uses, interestingly enough, a catalytic coated wire which is heated to sense the hydrocarbon vapors in the purge stream from the canister to modulate the additional air coming in. So it is, indeed, a vapor carburetor. But even a gadget of this complexity, while directionally it worked, did not quite in actual tests do the complete job. So even a piece of equipment of this type would have to be improved to do the job the way we think it ought to be done so as to avoid interaction completely.

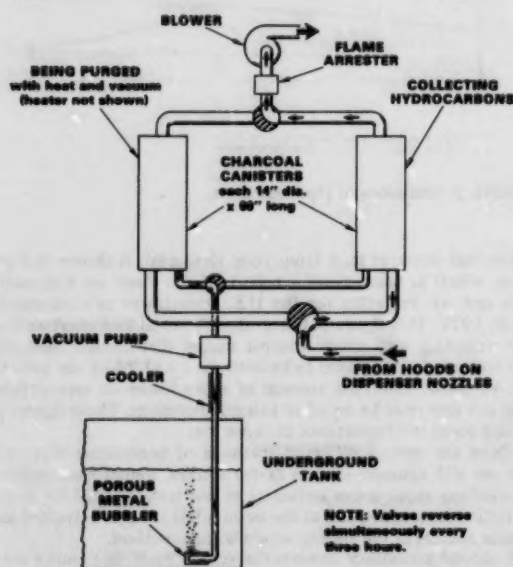


FIGURE 6: Simplified Schematic RB&W-Tokheim System.

Most of the service station control concepts have already been covered here this morning. Basically, most involve displacement to various means of disposal. Regarding the vehicle interface, I think all we've mentioned this morning is the tight-fill idea, merely putting a seal on the clearance between the nozzle and the fuel tank filler. There is also the possibility of a so-called vacuum cleaner connection which would be a loose connection with a pressure depression imposed. Finally there is the concept of a "dry break," which would be required with the concept of a collapsible tank.

Our Harrison Radiator Division (our heat exchanger experts) took a look at the idea of improving the condensation of vapors coming out of the tank with a heat exchanger around the nozzle. As Don mentioned, the low temperature liquid fuel going in should condense some of the vapors coming out. It was a cute idea and worked to some extent, but the extent of the control wasn't nearly enough to do the required job.

The R.B. and W. system (Figure Six), we think, is the kind of thing that appears to take care of all the requirements nicely at the service station. This system employs charcoal canister storage. It uses the so-called vacuum cleaner approach, which ideally would apply to all the cars in the population; stores the hydrocarbon vapors on charcoal; and removes the stored vapors for condensation back in the underground tank supply. In principle at least, this system looks like the obvious way to do the job at the service station. Certainly it would cover all the bases in the best way that we have seen.

Finally, then, to consider Don's question of how these two methods appear with regard to the atmosphere, this curve (Figure Seven) shows tons of hydrocarbons per day vs. years. We used the Los Angeles Basin as an example area. You see a rise in the total

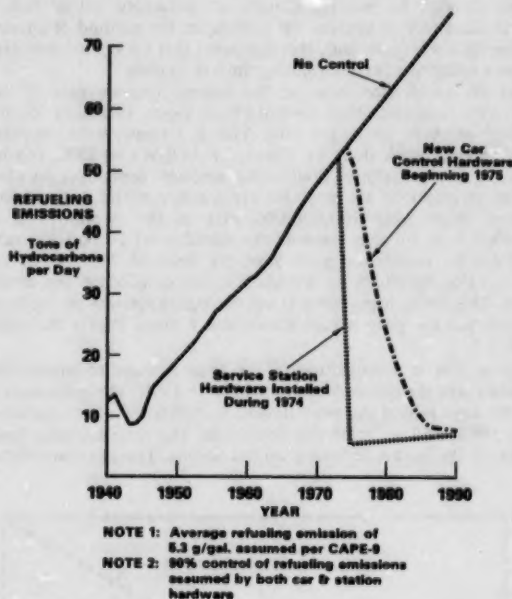


FIGURE 7: Los Angeles Basin Automotive Refueling Emissions.

tons of refueling emissions with increasing car population over the years from 1940 to 1990 if no control is assumed. In the case of service station approach, you will note very rapid reduction in the total emissions you could achieve, assuming one year's time for conversion.

The normal 10 to 15 year car replacement stretches out the time required to reach full control effectiveness. In summary, then, in the view of General Motors, the service station control of refueling emissions allows an ideal regional solution to a regional problem. Such control also carries with it the possibility of very rapid progress where the need exists, without imposing the cost and inconvenience on those areas of the country that don't require control.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you, Mr. Martens. Our next speaker is not on your program—Mr. Bruce Simpson. Mr. Simpson is Executive Engineer of Emission Control Planning, Ford Motor Company of Dearborn, Michigan. Mr. Simpson.

AN AUTOMOBILE INDUSTRY VIEWPOINT (II)*

by
Bruce Simpson

Thank you, Don. We are all concerned with the best methods to control this important source of hydrocarbon emissions from refueling losses. We'll be considering a variety of ways of doing so. You've heard a couple of ways this morning, and you will be hearing more later today and tomorrow.

Given this variety of control methods, how can we select the best method? What do we mean specifically by cost-effectiveness? How do we quantify this important item so that the right decisions can be made for the nation—decisions that represent the best balance for everybody? Today I would like to address this important subject. To do so, I will summarize a report which we prepared and presented to the Environmental Protection Agency in October of 1971—a little over two years ago.

Don Olson mentioned some of his figures had gotten out of date in two months. In two years, mine are definitely out of date. I present them to you because the technique, the method of arriving at these figures is important. It is this point that I want to leave with you, as a technique for determining the best system.

Let me summarize some of the assumptions we used in this study. We assumed that hydrocarbon vapor emissions during refueling are 0.32 grams per mile. This is a conservative estimate based on later work done by Olson, by APRAC, by EPA, and by others. It may actually be double that amount, depending on what kind of assumptions are made for vapor pressure and so forth. We assumed there were 100,000,000 cars in the nation. This is somewhat low. We also assumed the addition of 10,000,000 new cars into the population each year. We assumed 250,000 service stations. For simplicity of calculation, we considered the entire nation. This method probably is not the right approach on the basis of need, but for purposes of illustration I think it gets the point across.

Figure One is a projection of the total tonnage of automobile emissions into the atmosphere from 1950 to 1990. The good news is that we have passed the peak in vehicle emissions, which occurred about 1968, and we're on the down side. The total emission from all cars on the road is definitely on the decline. This has come about

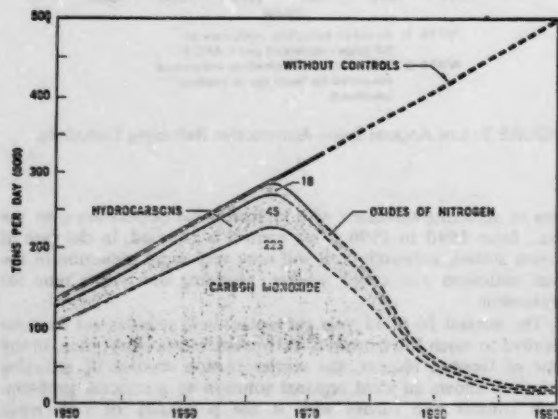


FIGURE 1: Nationwide Automotive Emissions.

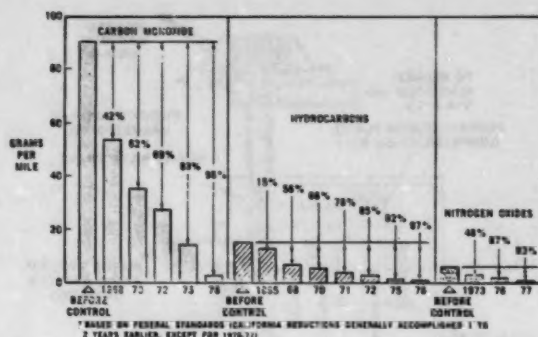


FIGURE 2: Accomplished and Probable Future Reductions in Vehicle Emissions.

as a consequence of the emission controls that have been put on cars over the years.

In Figure Two we see the effects of controls on carbon monoxide, hydrocarbons, and oxides of nitrogen. In response to Federal and California legislation, emissions from new cars are declining rapidly. As cars with these tight controls enter the population and replace older cars without controls or with less effective controls, the net result is the decline shown here. That is the good news.

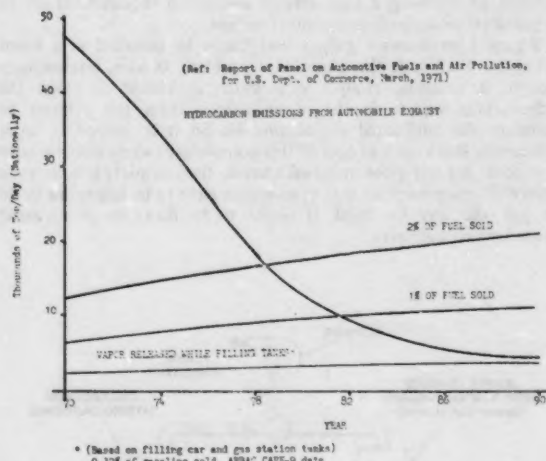


FIGURE 3: Emissions of Hydrocarbons.

The bad news, at least from your viewpoint, is shown in Figure Three, which is taken from a report of the Panel on Automotive Fuels and Air Pollution for the U.S. Department of Commerce in March, 1971. This figure indicates that the total hydrocarbon losses from refueling and vapor control during distribution operations were estimated at that time to be between 1 and 2% of the total fuel sold. By about 1980, the amount of vapor losses—at various points along the line—will be equal to exhaust emissions. These figures put in sharp focus the importance of vapor loss.

There are several different methods of controlling vapor loss. First, we will consider control at the station. Figure Four indicates hydrocarbon vapor losses occurring at the tank vents of the tanker, the station tank vents, and at the automobile itself. Controlling each of these sources at the station would be one method.

A second possibility involves the vehicle itself. In Figure Five we see a schematic drawing of a method not unlike the ones presented by Mr. Martens and Mr. Olson a little while ago. Our system is one that Ford conceived for a study we presented to EPA.

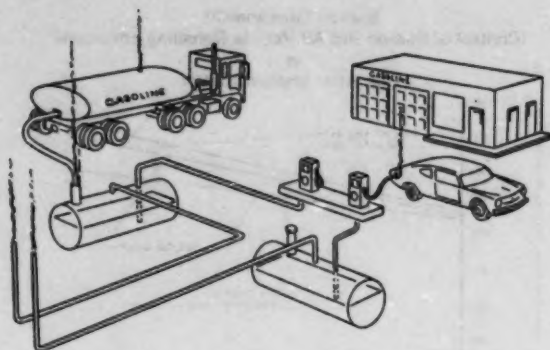


FIGURE 4: Present Practice Without Vapor Control.

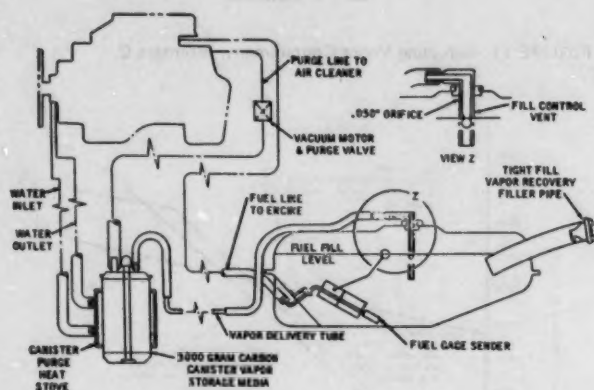


FIGURE 5: Tight Fill Vapor Recovery Fuel System with Vapor Containment in the Car.

In this concept, we used a rather large line through a restrictor into a storage canister, which at that time we felt would require about 3000 grams of carbon stored material. We now estimate that somewhere between 2000 and 2500 grams of stored material would be the right amount.

As Mr. Olson pointed out, tin cans full of charcoal aren't very costly. But as Mr. Martens pointed out, you can't do the job with just a can full of charcoal. You have to get rid of that vapor, you have to purge it, you have to consume it, all of which presents some formidable problems. These are problems of over-richening the engine, causing engine roughness and excess emissions, problems of proper metering, proper dispensing at the right point in the cycle, and so forth.

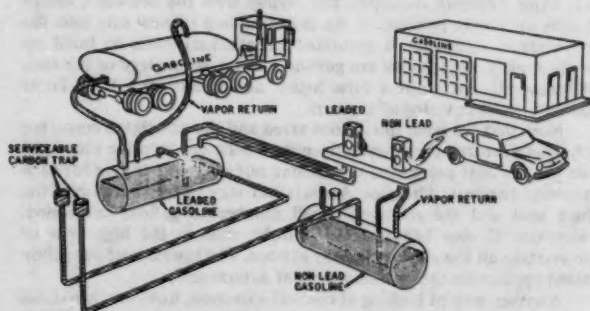


FIGURE 6: Equal Volume Displacement and Exchange.

As a means of handling the canister purging, we designed a heating retrofit consideration. Therefore, control of older cars cannot be accomplished practically by this method.

Another concept we studied as part of this cost effectiveness study concerned refueling containment at the station. Our idea was a vapor displacement and exchange system. We looked at the application of this concept two ways. First, on a prorated basis—that is to say, new stations, new pumps, new islands added in proportion to the new cars added on the road. In this way there would not be a massive tear-up of stations. We will describe this approach as alternate B. (Alternate A is containment in the vehicle.)

Another possible approach would be to effect the change all at once, to change all the stations, provide adaptors for cars. This is alternate C.

As I mentioned, we assumed a volume exchange concept. Some changes would be needed for implementation of this concept, one being a tight fill connection of some sort.

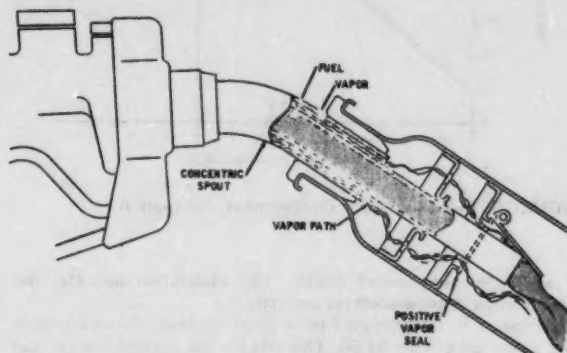


FIGURE 7: Tight Fill Nozzle and Filler Pipe.

Figure Seven shows one we designed. A unique aspect of this design is the "Positive Vapor Seal." When the nozzle is extracted, a trap door snaps closed, preventing vapor from escaping. Displaced vapors during refueling come up through the concentric nozzle.

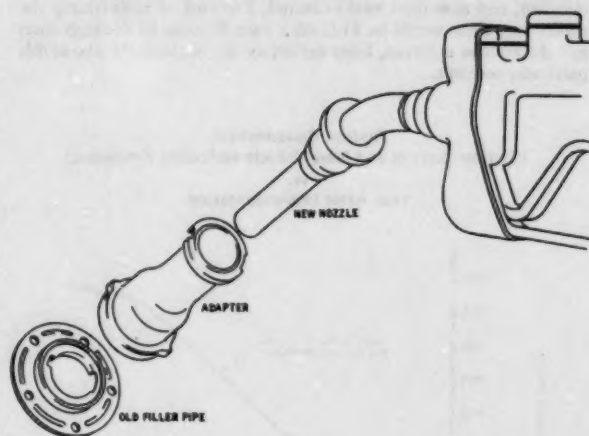


FIGURE 8: Retrofit Adapter for Past Models.

For cars on the road not equipped with the special filter neck, this would not be a practical concept. We figured there might be something like 16 adaptors required to connect one standard size of nozzle to the variety of different filler necks. This would seem to be an impractical, "negative incentive" kind of system.

Now, let us get to the subject of costs. Figure Nine refers to alternate containment in the vehicle. It shows the cumulative cost after each year of implementation. The system cost estimate was \$17.35. We also estimated that there would be a cost to the station

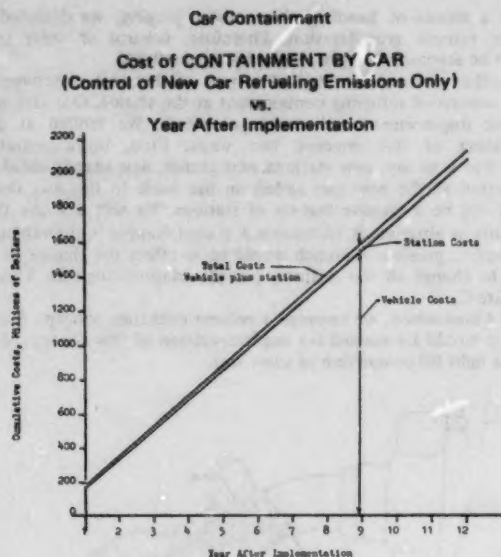


FIGURE 9: Refueling Vapor Containment, Alternate A.

of \$2.25 for the no-lead nozzle. This illustration indicates the accumulation of these costs for alternate A.

Alternate B, implemented on a prorated basis, shows a vehicle cost estimated at only \$1.60. This was for the positive closure trap door arrangement to prevent vapors from escaping. The major cost of this system is in the station. We figured the incremental cost to be \$800 per pump added, with an additional operating cost of \$675 a year.

Under alternate C, the whole job of converting the stations is done all at once. At an estimated cost of \$4,600.0 per station, you can see that the effort would amount to almost \$1.2 billion dollars to get started. Concrete would have to be torn up, new hardware installed, and new filler necks created. The cost of maintaining the filters thereafter would be \$125.00 a year. Because of the high costs and difficulties involved, I am definitely not enthusiastic about this particular concept.

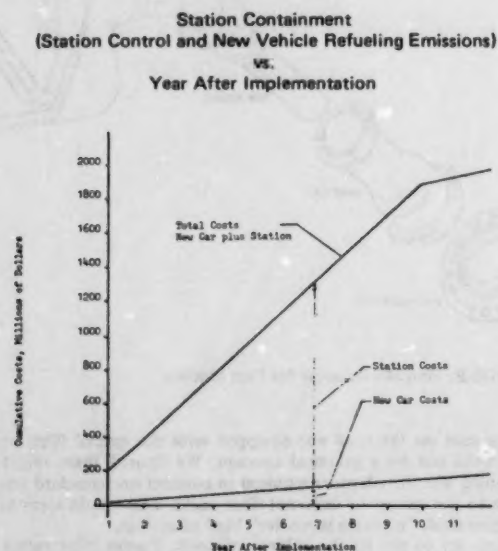


FIGURE 10: Refueling Vapor Containment, Alternate B.

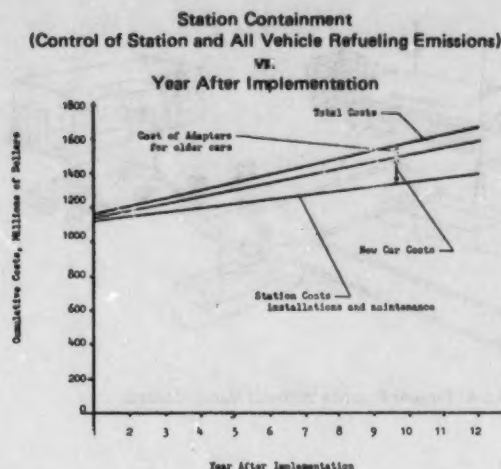


FIGURE 11: Refueling Vapor Containment, Alternate C.

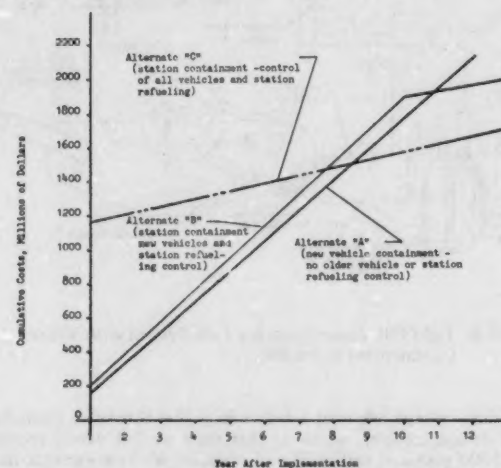


FIGURE 12: Refueling Vapor Containment, Costs of Alternate Containment Systems by Year of Implementation.

Figure Twelve is a summary of the cumulative costs for each of the alternatives. We want to look at how effective each system is.

Notice in Figure Thirteen the number of gallons of fuel not admitted into the atmosphere—from one to twelve years—on each of the three different concepts. The savings with the new-car concept builds up slowly because of the slow build-up of new cars into the population. Alternate B (prorated installation) starts to build up more rapidly because we are getting a larger percentage of the cars. Alternate C starts out a little higher and builds up a little faster because we're covering all the cars.

Now that we have the gallons saved and the associated costs, the obvious next step is cost-effectiveness. Divide one into the other and we get the cost per gallon of gasoline not emitted per year for each separate concept. Alternate A starts out very poorly because of the high cost and the relatively small number of gallons controlled. Alternate C also begins rather slowly, due to the high cost of converting all the service stations at once. The lowest cost per gallon saved appears on the prorated basis of Alternate C.

Another way of looking at cost-effectiveness, however, is to look at cost per gallon versus the number of gallons not emitted. This is important, too, if we are to be concerned about total emissions. Here we see the three alternates compared in this way. The small

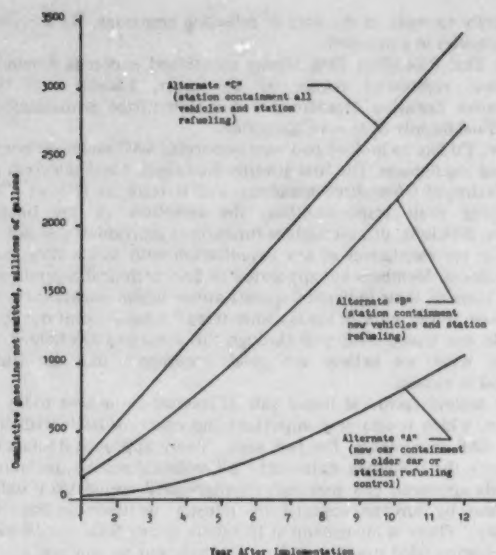


FIGURE 13: Refueling Vapor Containment, Gasoline not Emitted for Alternate Containment Systems vs. Year After Implementation.

triangle on each curve represents the total number of gallons not emitted into the atmosphere in 10 years. There are some important differences. Concept A saves about 750 million gallons in 10 years. Concept B saves about 2½ billion gallons, while concept C saves about 2½ billion gallons. (See Figure 15.)

Figure Sixteen shows cumulative gallons saved over a period of ten years and the cumulative cost over ten years, shown as an overall cost for each alternative system. On this basis, Alternate C turns out to be the most cost-effective arrangement, with a cost of about 15¢ per pound of hydrocarbons not emitted over a 10-year period.

Alternate B is slightly less cost-effective, but much more practical, with a cost per pound of around 20¢. The cost for Alternate A is around 35¢, but, as we discussed earlier, it saves

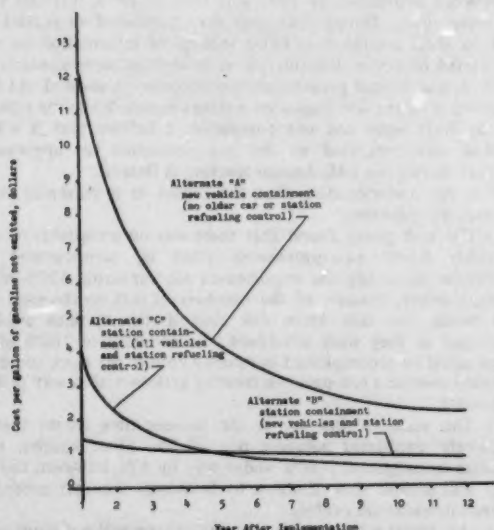


FIGURE 14: Refueling Vapor Containment, Cost-Effectiveness of Various Alternate Containment Systems by Year of Implementation.

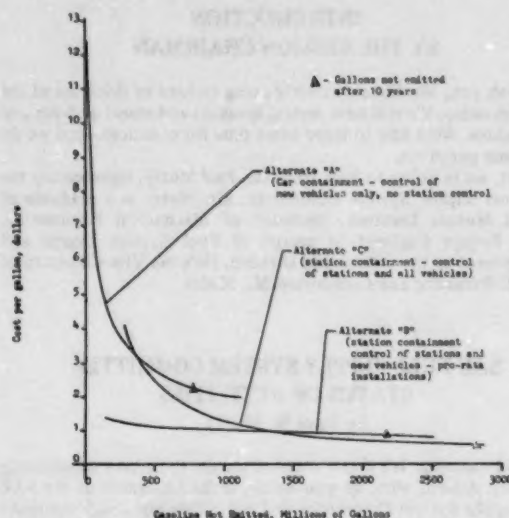
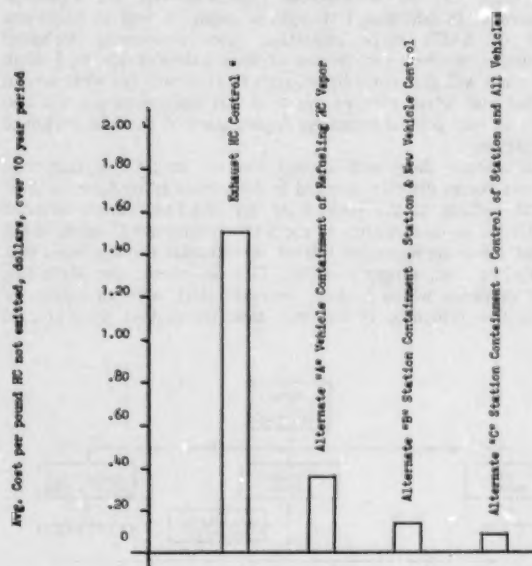


FIGURE 15: Refueling Vapor Containment, Cost-Effectiveness of Alternate Containment Systems vs. Gallons of Gasoline Not Emitted into the Atmosphere.



(*) - Based on estimated cost increase of 1975 emission control system over 1972, and corresponding hydrocarbon emission reduction.

FIGURE 16: Refueling Vapor Containment, Cost-Effectiveness of Reducing Hydrocarbon Emissions Exhaust Control vs. Refueling Loss Control.

pounds of hydrocarbon emissions. This figure also shows, for comparison, the cost of controlling (eliminating) a pound of hydrocarbons by vehicle exhaust control methods.

At the time we prepared this slide, we were planning to use both catalytic converter and thermal reactor, at a design cost of around \$490 per car. That is not the system we're now planning, which uses the catalyst only, with a much lower cost. However, with the original system we figured about \$1.50 per pound. Let's say I cut it back to 75¢ per pound for today's system—it's still a very poor bargain compared to any one of these three arrangements and dramatizes the need for and value of refueling vapor control.

Thank you very much, ladies and gentlemen, I hope these comments have been of interest to you.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you, Mr. Simpson. We're going to have to think about the time remaining. We still have several speakers and about an hour and ten minutes. We'd like to leave some time for questions—and we do have some questions.

Next, we're going to hear from Mr. Paul Mutty, representing the SAE Fuel Supply System Committee. Mr. Mutty is a graduate of General Motors Institute, Bachelor of Mechanical Engineering, Senior Project Engineer in charge of Fuel System Design and Development at the Oldsmobile Division. He's the Vice-Chairman of the SAE Refueling Sub-Committee. Mr. Mutty.

SAE FUEL SUPPLY SYSTEM COMMITTEE STATUS OF ACTIVITIES by Paul R. Mutty

Good morning. It's a real pleasure for me to be here substituting for Larry Arnett, who, as you know, is the Chairman of the SAE Fuel Supply System Committee and unfortunately could not make the meeting today. My objective is to present an overview of the status of activities within this committee, the Fuel Supplies Systems Committee, with respect to refueling emissions. I have also been asked to review with you a new SAE recommended practice for measuring this type of emission. This procedure was developed by a task force of the Automotive Emissions and Air Pollution Committee. In addition, I thought it might be well to point out some of SAE's more important rules concerning technical committee members and the use of their technical reports. I think these rules will give you a little better feel not only for what we can do, but also what, perhaps, some of our limitations are. I'll also review in very general terms the organization of the SAE technical committees.

Let's begin, then, with a quick look at the SAE organization. The task forces directly involved in the subject at hand are outlined on the bottom of the page. Note that the Fuel Supply Systems Committee reports directly to the SAE Automotive Council. It has several sub-committees, all related to technical investigations that pertain to fuel supply systems. One of them, the Refueling Sub-Committee which I chair, concerns itself with all aspects of automotive refueling. It has two task forces that were created

specifically to work in the area of refueling emissions. We'll review their activities in a moment.

The Test Procedure Task Group mentioned earlier is shown in the lower right-hand corner of the chart. Liaison with the Evaporative Emission Measurement Sub-Committee is maintained by the Fuel Supply Systems Committee.

Now, I'd like to look at two very important SAE technical board rules and regulations. The first governs the function and selection of SAE Technical Committee members, and it reads as follows: "In discharging their responsibilities, the members of the board, councils, divisions, or committees function as individuals and not as agents or representatives of any organization with which they may be associated. Members are appointed to SAE technical committees on the basis of their individual qualifications which enable them to contribute to the work of these committees." I might point out that this rule has served SAE well through the years and has helped to produce what we believe are good documents that are truly technical in nature.

The second technical board rule of interest to us here today is this one, which is also very important and concerns itself with the use of SAE documents. The rule says, "Every approved document shall carry the following statement: 'All technical reports, including standards approved and practices recommended are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary.' There is no agreement to adhere to any SAE standard or SAE recommended practice and no commitment to conform to or be guided by any technical report." The products of SAE Technical Committees constitute engineering advice and recommendations. Voluntary usage, therefore, is an essential characteristic of SAE technical documents and standards.

Let's move on to the areas of SAE involvement in the field of refueling emissions. In May of 1972 the Refueling Sub-Committee held a half-day seminar on The Control of Refueling Emissions, a meeting similar to this one, but on a much smaller scale, in Detroit. During a meeting of the Sub-Committee immediately following the seminar, a task force was established to study the problems of the interface between the refueling nozzle and the vehicle fill-pipe. The task force was to consider both retrofit and future design.

Early in the operation of the group, however, which was then named The Fill-Pipe Compatibility Task Force, it was decided that the problem of retrofitting should be handled by a separate group. A second task force named The Retrofit Task Force, therefore, was established in September of 1972. The scope established by the Retrofit Task Force and formally adopted by the Refueling Sub-Committee is to determine the feasibility of control of 100% of the refueling losses and investigate means for maximum control of losses during refueling of existing gasoline-fueled wheeled vehicles normally refueled at service stations.

Between September of 1972 and June of 1973, this task force met seven times. During that time they contacted all parties that came to their attention as being sources of information to meet their stated objective. Information secured from these contacts was reviewed, and several personal presentations were allowed. At their last meeting, work was begun on a status report. While the report is now in draft form and not completed, I believe that it will be finalized and presented to the sub-committee for approval in February during the SAE Annual Meeting in Detroit.

It is my understanding that the report as it currently stands indicates the following:

- 1) The task group found that there was no acceptable method available—both equipmentwise (that is, components) and systemwise—to satisfy the requirement for capturing 100% of the vapors. Further, because of the numbers of cars on the road with open vents, the task force felt that if the systems available functioned as they were advertised, the recovery of 100% of the vapors could be accomplished in roughly 75% of the cases and doing so would require a low-pressure creating system within very delicate boundaries.

- 2) The state of the art at the present time shows that no completely significant solution is available. Since another more elaborate investigation is now under way by API, however, the task group will review their findings to determine whether acceptable methods or hardware evolve.

- 3) The report will note that the task group will not continue to investigate on a regular basis, but will meet during the general period of Refueling Sub-Committee Meetings to review developments in the field and perhaps to reopen its study if deemed necessary.

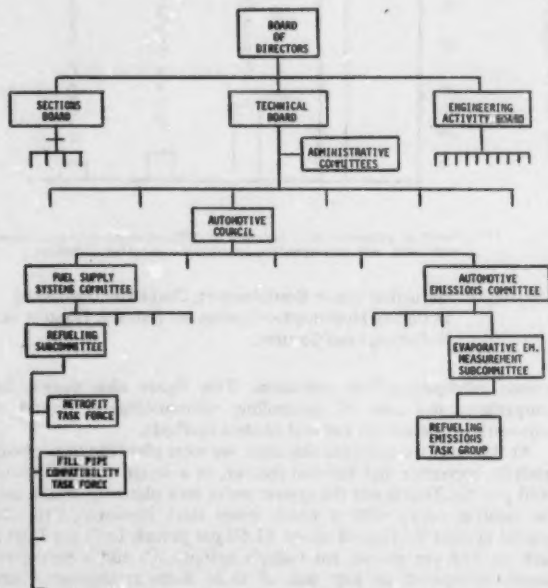


FIGURE 1: SAE Partial Organization Chart.

4) This interim report will also include a listing of task force members and all contributions, both written and verbal.

Obviously, developments during the last few months, and some of the presentations to be made here during this two-day seminar could, of course, result in further task force meetings and revisions of the status report before a formal presentation to the Refueling Sub-Committee. I'd like to point out that the chairman of this particular task force is Mr. Bill Hansel.

The Fill-Pipe Compatibility Task Force adopted this charge, which was later approved by its parent sub-committee: "To recommend an interface with a minimum number of standard dimensions between fuel supply source and auto fuel receiver for new and future equipment where vapor control is required." The group has met on numerous occasions in Detroit and Chicago in an effort to accomplish this task. They began with a general review of existing standard connections for fluid handling and proceeded to develop a set of dimensions to accomplish their stated objective.

The first set of dimensions was presented by a task force member approximately one year ago. The original proposal provided for a standard fill pipe that would interface with a specified spout and seal arrangement. After discussion, the task force suggested that the proposal should perhaps be revised to include the seal in the fill pipe. A modified proposal has been presented to the task group. I might point out, however, that the proposed set of standard dimensions has not yet been completely refined nor presented to the Refueling Sub-Committee for approval or discussion.

During the discussion of the task force's assignment at a meeting of the sub-committee some months ago, it became apparent that a number of variables would have to be eliminated before the job could be completed. An example of these variables is the question: Should the proposed interface be such that a vehicle equipped with it can be refueled with conventional equipment in a non-controlled area? Obviously, this type of question can have a significant effect on the final product of the task force.

Members of the group and the sub-committee have since been considering and reviewing that discussion. Many of the variables, of course, still exist. I'm very optimistic that this two-day meeting will be helpful to us in eliminating some of them or at least in putting them in proper perspective. Several of the task force members are here today, and I'm sure that they'll be wanting to meet in the near future to review all the inputs they receive. Should you have any such inputs or suggestions of any kind, please contact me or the Chairman of this task group, Mr. Glenn Moore.

Some months ago the Refueling Emissions Task Group was established by the Evaporative Emissions Measurement Sub-Committee. Their objective was to write a comprehensive procedure for measuring refueling emissions. The Fuel Supply System Committee has been kept aware of the various drafts and has provided input to the task group. Their product was completed and approved by the SAE Automotive Council as recommended practice number J1045 during this past summer. Its formal name is Instrumentation and Techniques for Vehicle Refueling Emissions Measurement.

The scope included in J1045 is: "This SAE recommended practice describes a procedure for measuring the hydrocarbon emission occurring during the refueling of passenger cars and light trucks. It can be used as a method for investigating the effects of temperatures, fuel characteristics, and so forth on refueling emissions in the laboratory. It can also be used to determine the reduction in emissions achieved with emission control hardware. For this latter use, standard temperatures, fuel volatility, and fuel quantities are specified."

I think you'll find that this publication does an excellent job of fulfilling its objective. It's a five-page document that includes discussion of such subjects as instrumentation requirements, with photographs; the test procedure, including some standard conditions; data requirements; and several appendices to provide necessary additional background information. SAE J1045 will be included in the 1974 Handbook. Meanwhile, it's available as a Handbook Supplement for SAE.

In addition to these specific activities, the SAE Fuel Supply Systems Committee and its Refueling Sub-Committee maintain liaison with all groups involved in the total vehicle refueling process. Included in those groups, of course, are the various SAE task groups, CRC, and API's EF14 task force. I'm certain that all of our members will be anxious to discuss the results of this seminar at our February meeting. At that time we'll also want to discuss what our

role with respect to refueling emissions should be in the future. Once again, any suggestions you may have would be very useful to us. Thank you very much for your attention. I've enjoyed being here. I'd just like to point out one more thing. If you do have any questions I'd be happy to answer them at the appropriate time. However, I must ask that they be restricted to my SAE activities. Thank you.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you. We have two more speakers and approximately 55 minutes, so perhaps we will get to some questions. We've heard about the control at the vehicle. We've heard a couple of industrial viewpoints, and something about the SAE. As an outsider I have no idea what it's all about, and I'd like somebody to break the code for me sometime. We'll now hear from the service station end of it from Mr. Manos, substituting for John Harkins of the Scott Research Laboratories. Mr. Manos is Research Engineer with Scott Research Laboratories, and for the past four and half years has worked on exhaust emission problems and refueling emission studies. Previously he worked with Mobil Oil and Ford Motor Company. Mr. Manos.

CONTAINMENT AT THE SERVICE STATION

by
Mike Manos

Thank you, Don. Scott Research Laboratories, under contract to the American Petroleum Institute, is currently performing a study of service station vapor control systems. The general purpose of the study is to evaluate three basic recovery concepts to obtain data on concept feasibility and cost-effectiveness.

The scope of testing basically includes evaluation at nine different test sites located across the nation. The tests are being conducted during the summer, autumn, and early winter periods at each site. The participating companies and locations of the test sites are: In California we have Atlantic-Richfield located in Pomona; Mobil Oil Corporation located in Fremont, which is in the Bay area; Standard of California located in Davis, near Sacramento; and Union Oil located in the City of Commerce, which is right here in the LA area. In Houston, Texas, we have a Shell facility and an Exxon facility where we conduct tests. In Whiting, Indiana, which is near Chicago, there is an Amoco test site. In central New Jersey we have Sun Oil Company and Cities Service. Six of the nine sites are in conjunction with operating service stations, and the other three are primarily research facilities.

Three vapor control concepts are being investigated. They are direct displacement—or vapor balance, as mentioned earlier today—activated carbon absorption, and refrigeration. The latter two—activated carbon and refrigeration—work in conjunction with the direct displacement basic system. Each concept or configuration at the test site has the design capability of controlling the vapors emitted. They are associated with the refueling of vehicles and with the delivery of gasoline from the transport to the underground tanks.

Seven of these nine test sites were equipped with the direct displacement system. Some of these incorporated small diameter orifices or pressure-vacuum relief valves attached to the regular 2-inch station vent to assist in the performance of the direct displacement system. One test site was equipped to evaluate both the direct displacement system and also had the capability for evaluating activated carbon adsorption. However, only limited testing has been performed to date with the activated carbon system in operation.

The refrigeration system for vapor control that's part of this program utilizes a 1-ton refrigeration system, and there's no compression of vapors during the condensation process. Also, this refrigeration system incorporates a blower to assist in directing the vapors from the vehicle tank back to the underground during refueling operations.

Performance tests are basically divided into two types. They are

the delivery of fuel from the tanker to the underground tank and the vehicle refueling operation—with some tests being conducted while both of these operations occur simultaneously. The data collection for this program has been completed for the first two seasons of the three-season survey, and right now we're actually halfway through the third season, which is the winter season. We started this third season collecting data in Houston, Texas, and unfortunately it was 83 degrees down there to start the winter survey.

Here is a quick summary of the results through the first two surveys, which are the summer and autumn survey. In conjunction with tanker deliveries to the underground fuel storage, 50 deliveries have been monitored, and the average loss, or the amount of excess vapor quantity emitted to the atmosphere for the direct displacement systems, has averaged about 5¼% by volume. Tests in conjunction with the refrigeration system encountered no loss to the atmosphere to date. Approximately six tests have been conducted.

With the activated carbon concept we have only one test data point at this time, and the loss was significantly less than 1%. Test data for direct displacement systems, which incorporate either a pressure vacuum relief valve on the vent pipe or a restrictive orifice, show a noticeable improvement over the standard open 2-inch vent pipe found in most stations.

With regard to vehicle refueling, 27 tests have been performed, which involved the refueling of 175 automobiles. For these tests, approximately a total of 2850 gallons have been dispensed, with the average resultant loss or excess vapor quantity equaling 8¼% by volume. By deleting one of the 27 tests where the data is somewhat in question and hasn't been quite straightened out yet, the average loss value calculates out to be reduced to about 5%. In vehicle refueling tests conducted in conjunction with the refrigeration system, which is essentially a closed system, we've encountered no loss at all.

No vehicle refueling tests have been performed to date with an activated carbon system in operation. It should be noted at this time that the results I just mentioned do not reflect refueling operations that would typically occur at a gas station for two primary reasons. First, all the vehicles involved in the vehicle refueling tests are 1970 or later model vehicles, all of which have evaporative emission control systems. These were selected to restrict the experimental design of the program so that the results could be analyzed in a more appropriate manner. Second, every precaution was taken to provide a leak-tight seal between the vehicle filler neck and the dispensing nozzle. This meant, in some cases, that the technician dispensing the fuel had to force the nozzle manually against the filler neck in a couple of cases to provide this leak-tight seal.

Currently available nozzles with prototype sealing arrangements were not sufficiently developed during the earlier part of this program to allow hands-off leak-tight vehicle refueling. So this forced restriction of maintaining a tight seal was enacted to aid in the collection of data. Therefore, the results of this program are intended to reflect service station vapor control system performance that could be expected pursuant to the actual development of a future nozzle-seal arrangement that fits essentially all vehicles and a population of vehicles which has no external venting, other than to the evaporative control system of the vehicle.

As mentioned before, the third season survey (which is the winter survey) is about half complete. This will continue on through the middle of December. During the course of the program so far, many of the participants involved have made minor design changes in their piping configurations, nozzle adaptation, and other control equipment hardware—all aimed at optimizing the recovery potential of their systems. This has been reflected in a substantial improvement in the recovery potential of the systems with time.

Other factors pertinent to the subject of vapor recovery will be evaluated and analyzed within the scope of this program at a later date. We're going to look at the installation, capital, and maintenance costs for the various configurations so that we can determine a dollar value per unit of hydrocarbon prevented from entering the atmosphere. We'll also look at operating cost and power consumption factors (this seems to be a very hot topic nowadays), and we'll evaluate underground tank diurnal breathing losses in conjunction with the recovery system. Thank you very much for your attention.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you, Mr. Manos. Before we proceed to the final speaker, I'd like to remind each speaker that we would like to have copies of the slides for the final production of the proceedings of this seminar. We now turn to the final speaker, Mr. Richard Southers, American Petroleum Institute. Mr. Southers will present the petroleum industry approach to vehicle refueling emissions, after which we will have time, it appears, for some questions. I've given some of the questions we've collected to panel members, who have studied them. I ask the panel members to come up here, and we'll answer as many questions as we can before 12 o'clock. In the meantime Mr. Southers, please.

THE PETROLEUM INDUSTRY APPROACH TO VEHICLE REFUELING EMISSIONS CONTROL

by
Richard Southers

One of the earlier speakers this morning made a point of the fact that he was speaking of an automotive approach. Unfortunately, the program says I am speaking about the petroleum industry approach. So I will be carefully audited by many people in the audience this morning.

The control of vapors that are emitted by petroleum products has long been a subject of study and interest in the petroleum industry. Until recent years, however, the interest was centered on the control of vapors for reasons of product conservation and safety.

The attendance at this conference, I think, is adequate testimony to the fact that there is another reason for interest in the control of these vapors today. That reason is, of course, the effect upon the environment that such emissions may have or, more simply, clean air.

Over the past 50 years, the service station has grown and become a part of almost every business community. It is only natural that the thought processes that developed within the industry during this period would be reflected in the manner in which the industry would set forth to seek answers to the challenge that the control of refueling emissions represented. In my remarks I am including in the category of refueling emissions both those that are generated at the time the vehicle is refueled and those that are generated when the service station supply tanks are refilled.

Safety considerations for some time have called for certain controls to be established over the vapors which are released during the filling of underground tanks. Also, the benefits which might be derived from the use of submerged fill have also been investigated by most oil marketers. In the light of this past experience, it was logical for the underground tank to be the source of most of the thinking about control of these emissions in the early phases.

In 1971, when through API a survey of emission control activity by the oil companies was made, it was learned that six companies had already been investigating the feasibility of collecting vapors from underground tanks. Only one company could report an investigation into the control of vapors released from the vehicle.

At that time, only one equipment supplier was actively trying to stimulate interest in a means of capturing the vapors coming from the vehicle. His entry into the field was occasioned upon the belief that the system could be sold on the basis of an economic return. However, even with the added incentive of being able to offer a system as a solution to environmental regulatory problems, the project was finally dropped because of the technical difficulties that were encountered.

Other people were interested, were experimenting, and were developing equipment. However, there was only the one supplier that was actively promoting. I want to note the difference. Our first investigation into the state of the art for controlling refueling vapors disclosed that there was no full-scale, field-tested equipment available at the time.

Recognizing the need to get things moving more rapidly in this field, the industry assigned to API the responsibility for initiating a program which could give direction to the activities of both oil companies and equipment suppliers. As a first step in establishing this direction, the Refinery Management Services of Pasadena was chosen to prepare a cost-effectiveness study of the various concepts for control of refueling emissions. It was felt that such a paper study could assist in identifying those concepts or systems which possess the greatest potential for a cost-effective solution.

That activity has generally been referred to as Phase I. Many of you actually have copies of the report that was prepared on this activity. Phase II, which was just reported to you, is a full-scale, on-site evaluation of four of the concepts which were selected from the information generated in Phase I. Phase II is divided into two parts: one concept for the control of vapors on the vehicle, assigned to Olson Laboratories for evaluation; and three concepts for the control of vapors at the service stations, assigned to Scott Research Laboratories for evaluation. The presentations on both of these studies that you heard this morning prove there is a possibility of solving this problem both ways.

The purpose of all of this activity, however, is to give guidance to those who manufacture equipment as well as those who utilize it in the control of refueling emissions. We have no intention of selecting or recommending a system for the industry. The information generated will be available to any party having a valid interest in the subject. These API projects are not to be construed as the total effort to find answers to the problem at hand.

In recent conversations I have had, at least six oil companies have informed me that they are continuing with a proprietary type of investigation for equipment or systems which might be used in this area. Four companies are installing equipment at actual locations that would have been included in the project here. With the timetable that was established, however, the equipment could not be secured soon enough to be included in our study.

I think we need to understand that although a lot of thought has been given to these studies, the setting up of a plant that can produce the required numbers that have been envisioned is not a simple thing. It is understandable that those people who would be the potential suppliers will not tool up until there is a much clearer indication that this equipment is what the industry and the regulatory people are ready to buy. Therefore, even though the literature and some prototypes are available, we initiated this study on a push basis. Companies ordered equipment, and it was not available in time to get started with our project.

Rather than put the effort aside, though, the four companies I know of at this point are currently installing or have installed refrigeration-type systems or refrigeration compression systems. We will be gathering more data within the industry concerning other means of control in addition to the large number of displacement systems that Mike Manos reported to you. Several companies are moving forward with the installation of equipment in anticipation of the controls that, as they see it, are coming in various areas.

Primarily, the work that is being done today, however, is in connection with collection of the vapors from the tanks, since this seems to be a much clearer area. One company advised me that in the past month it had let contracts to equip all of its stations in Los Angeles County for the collection of vapors from the underground tanks. Other companies have stated that they are now providing for the installation of the vapor collection lines, even though they don't know exactly what they will be connected to, in new stations as they are being built.

All of the activities related to the capture of vapors from the vehicle share one common problem, though, and that is the mating of the vehicle with the station's collection system. I'm certain that these difficulties will be talked about more fully tomorrow.

Besides the difficulties of mating these systems mechanically, other considerations make this interface at the vehicle one of the knottiest of problems we have. The pumps, or the dispensers as you please, are a key link in the interface. These devices are already subject to approval in order to satisfy specifications of regulations concerning weights and measures and fire codes. Any alterations to these devices in order to facilitate the collection of vapors must be done in a manner that will be compatible with the existing regulations already complied with.

Because there are no existing standards for vapor collection systems—other than the voluntary industry standards generated through the SAE, ASTM, and ANSI—suppliers have no single

standard they can refer to to say what is needed. Because of this problem, and the need to be able to meet the existing regulations, there is a real gap growing in the process of perfecting systems for use.

Because of this gap, API is now contemplating a program of equipment evaluation. The evaluation would be done by an independent agency relative to the performance of the equipment as it would concern all three regulatory bodies—environmental controls, weights and measures, and fire. But this is not an announcement of the program. As I say, we are only contemplating this plan. How the plan could be accomplished is a very difficult matter. But we see here a void which does need to be filled, and we want to step in so that the program can move forward. We will welcome suggestions from any others who have ideas on how this program might be accomplished rapidly.

Oil companies do not want to find themselves in the position of alienating one agency while trying to satisfy another. Something must be done. This lack of standards and approval procedures has proven itself to be a considerable impediment to the rapid process of development.

Potential suppliers of equipment need to be better advised so that they can gear up for production. At the moment, they lack the assurances for making such expenditures.

To my knowledge, no oil company is presently considering any method for recovery of storage tank vapors other than transfer to the delivery vessel. Because so much of the product delivery is accomplished by common carrier transport, it has become necessary to try and develop industry standards for the vent lines and the connections to the transports. We have been working on this problem within the industry, attempting to develop an industry standard for these connections. Companies with their own transports naturally can make their own guess if they so desire, then go ahead and equip. If they have guessed wrong, they change the fitting. The common carrier, however, who serves half-a-dozen oil companies is still hanging back saying, "I don't want to put a system on my transports until I know what the system is going to be." Hopefully, we will develop that system.

One fly in the ointment seems to be appearing, though. Some of the testimony heard at recent hearings, as well as some of the indications contained in recent news releases from EPA, indicate that the industry's thinking on these connections is not quite the same as the regulatory thinking. It may take us a little while to iron this problem out.

Basically, we have said that the connection should not be a dry-break connection because of the possibility in bottom loading of hooking up to the wrong place. This practice is a rapidly increasing one within the industry. On the other hand, the regulatory people are saying we should have a dry-break connection because—if the connection is broken and there is any condensation in the line—they don't want the condensation to run out.

So, we are both looking at safety operational considerations—but there are two directions to look from. These problems must be ironed out soon enough to allow the common carriers to get their transports converted. Then all of the station people now trying to equip with vapor connection returns will be able to have those vapors picked up when the transports arrive.

In the past, there have been some accusations that the petroleum industry has not fully cooperated in trying to meet the goals that have been established for cleaning up the environment. I think you can see from what has been said here that we have been, and still are, very busy in seeking proper solutions to the problems and the challenges contained in these goals. The only criticism which might have some basis is that we should have started sooner. The oil industry's crystal ball, however, failed to disclose some of the problems that have recently appeared.

We earlier sought counsel from the regulatory people as to when we might expect to be faced with the problem of collecting these vapors. The earlier prognostications we received held that the problem probably would come around 1977, when the vapor emissions had been reduced from other sources to a point where the refueling emission vapors would then be a very sizeable part of the total emissions. We thought we could move according to this appraisal, and we did actually establish our committees. But things were not going as fast as we might have liked them to, until San Diego. There is no question but that San Diego's ordinance provided the necessary impetus to get a coordinated industry program rolling. For this effort, I am sure that all of us, both industry and regulatory bodies, owe San Diego a debt of gratitude.

On the debit side of the ledger, however, there was a lack of recognition of, to coin a phrase, "the ecology of commerce." Any disruption of the interplay between supplier, user, regulatory bodies, and the consumer that a regulation may cause cannot be ignored, any more than can biological or sociological imbalances. Hopefully, this seminar will help get all of these factors in their proper perspective and assist us in arriving at solutions acceptable to all.

DISCUSSION PERIOD

Mr. Walters: I'd like to ask all of the panel to come up here, now, and we're going to go through the questions. If you need to stand up, go ahead. We're not going to take a break, because with this unruly crowd we'd never get them back.

There would seem to be quite a few questions—I've already given some questions to some of the panel members. I'd like to start with Mr. Winkler. Would you take one of your questions and see what you can do with it? Then we'll go to Mr. Olson.

Mr. Winkler: The first question I have here is: "Give more detailed information on those states which do not require service station vapor controls in their plan. Could this mean that other states could adopt a program which would not require service station vapor controls? J. A. Todd, Dresser Industries." Well, yes, we are primarily interested in those people who can't meet the ambient air quality standard, and they have tried various control measures. One of those measures would be control of service station vapors. Those states that don't have a particular problem, or don't have a great deal of reduction to attain, we are not interested in—I mean if they can do it without vapor control in service stations then that's their prerogative.

Mr. Walters: Since each panel member will have several questions, I'll ask you to be the judge. Pick the toughest one first and answer that. Mr. Olson, before you start I have a couple more you might take a quick look at.

Mr. Olson: Let me answer the one question that I had in advance here, even though it's not really tough. It's a question from Ronald Jackson from the State of Arizona in regard to the Federal Test Procedure Exhaust Emission Measurements we have made. This is also a question for Stu Martens, so he might be listening to the question.

Mr. Jackson is asking whether we performed that test procedure immediately after the refueling operation. The reason for the question, really, is would the emission values return to pre-refuel retrofit after some driving? He comments that the results appear to be the result of slightly rich operation and asks whether there is a saturated canister, or is there a continuous pullover from the tank. To answer the last question first, there's not a continuous pullover from the tank with this system—and probably not with Stu's more sophisticated system, either.

In answer to the first question, we did perform these emission tests directly after refueling. Now, by directly after refueling we, of course, mean at least a minimum of 12 hours after refueling. The cars were refueled the day before, and emission tests were made the next day—following the cold soak as specified in the procedure. Certainly, as time goes on and the car is being driven, this saturated canister would tend to be purged of hydrocarbons, and you would expect to get a slightly lower carbon monoxide values over a period of time.

That's a function of the design—of the system and the purge rate through the canister. It may therefore well be that on the average, you wouldn't see too much of a reduction in the carbon monoxide increases that we reported. However, we didn't do an extensive study of that question, so I can't be sure of that point. Stu, do you want to add anything from your own data?

Mr. Martens: I'm in general agreement with what you say, Don. I might indicate that the general procedure followed in our interaction tests were based on the SAE procedure that Paul has passed out to the lucky twelve.

Mr. Walters: Mr. Martens, you had quite a bunch of questions. Pick out a representative one, and give the person who answers the question—then try to give as brief an answer as possible, but complete.

Mr. Martens: I had a couple of early ones that I was able to look at. The later ones may or may not be more difficult. I was trying to listen to Don's answer. I think this one would be appropriate:

"Since charcoal systems will be installed in 1975-plus vehicles, does the 30% CO increase reflect data on 1975 to 1976 catalyst prototype vehicles?"

In the first place, the 30% represents measurements on a 1973 car. There were no catalyst systems involved. In the second place—perhaps it's necessary to clarify—the charcoal system that was being referred to presumably by the question as being installed on 1975-plus cars really is the production evap system that's now on 1974 cars and was also on 1973 cars, in addition to the experimental refueling emission control system. So the 30% exhaust carbon monoxide interaction we're talking about is over and above what the production evaporative emission control system caused.

If I may make one more point, the closeness of the 30% number that we showed and the 25% that Don Olson showed makes it appear that the level is very well-established. I want to assure you that it is not. In the first place, it is very difficult to measure the exhaust interaction of evaporative emission control systems. Secondly, even the philosophy for making that measurement is not well-established. So we certainly wouldn't want anybody to go away from here with the idea that beyond question the interaction is 25% to 30%. The actual level is not well-established.

Again, to address this question, the interaction on a catalyst-type exhaust system is another matter. We don't have measurements on that.

Mr. Walters: Okay. Now, I have here a question, which seems to be interesting, for EPA. I understand we have Mr. Richard Penna here from the EPA Mobile Source Enforcement Division, and maybe we can prevail upon him to answer it. It has to do with compliance dates and criteria for establishing compliance dates. Throughout all this discussion I didn't see too much tie-in with these dates that we heard earlier—that is, whether they're realistic or not. Mr. Penna?

Mr. Penna: Okay. The question that I can specifically answer is: "What were EPA's criteria for establishing compliance dates, including interim dates, compliance schedules, awarding of contracts, completion, etc.? Considering the known state of the art—little experience by practical application with reality, safety, metering devices, and the like—how can any valid dates be established at this time?"

The early date for compliance schedules in the regulation was more for our purposes at EPA to determine what the compliance or noncompliance would be. We want to get a document from those people who are going to be effected to see that there is going to be a commitment. Now, what is contained in the compliance schedule can be dates in which certain increments of progress are going to be achieved. This is what we want to see.

In terms of the actual construction date in the regulation, I think that in most places except for a couple of cities in Texas, we're talking about January 1, 1975 for the Phase I, the underground storage, and I think January or February (I have to have my memory refreshed) for the Phase II. The reason that we've done this is to allow time for ground-breaking. We know that all construction can't start on that date. It's a problem of contractors and this sort of thing. But this is what we're looking for in compliance schedules—to see if some people can start on January 1, 1975. Others can start June.

We can phase this thing through with ultimate compliance by 1976 for Phase I, 1977 for Phase II. I think the actual crux of the question is how can we establish dates at this point in time. We must do so under the mandate of the Clean Air Act. The Act says that you have to meet standards as expeditiously as practicable, and that's a quote.

It also says that in terms of regulations which states submit to EPA for approval or regulations that EPA promulgates, there must be an orderly compliance, an orderly method of compliance included in that regulation. So in order for EPA to follow the law which Congress passed and the President signed, we had to establish these dates.

In terms of refinement, certainly we're open—there is a 30-day comment period for all the regulations as proposed. If there's a question, if there are questions on interpretation of the regulation, if there are questions on actual compliance dates or what is meant, we would certainly be receptive to getting these comments.

Mr. Walters: Thank you, Mr. Penna. We have an unlimited supply of EPA personnel here at this meeting to handle all questions. Mr. Manos has a quick reply to his questions.

Mr. Manos: Okay. I have one question here that asks: "The testing that was done on the refrigeration system, was the unit—or

the system—in equilibrium prior to running any tests?" The answer to that is yes, as measured by pressure in the system. Most of my other questions have to do with further analysis of the data, which has not been completed. The program is still in process.

Mr. Walters: Thank you, Mr. Manos, Mr. Simpson?

Mr. Simpson: I have one question here that begins: "Ford said that the use of adapters for vehicle filler pipe to universal nozzle connection was totally impractical. Why so? Is this not a reasonable and comparatively low-cost solution to the problem of the nozzle-filler interface?" Low-cost, yes. Practical, probably not from a policing standpoint. It would be necessary to get these adapter nozzles to the right car at the right time. Two cars, the same model, come in. Are you going to have double sets of them? I think some 16 to 19 of them would be required. It just seemed like a very difficult thing, an extremely difficult thing to police. It would be a lot of bother, and chances are they might not get used. That was the basis for my comment.

Mr. Walters: Thank you. Let's see, Mr. Olson?

Mr. Olson: Well, I have three or four questions. I'll take this one, which I think is very pertinent, from Jack Gockel of Clean Air Research. "How do you get a savings in gasoline by burning evaporative emissions in an engine when 1975 and later engines will be designed to operate at air fuel ratios for best economy?" Of course, that's a good point. We did our analysis with and without the fuel savings analysis as part of the consideration. It's a controversial point, and our assumption was that you could in fact use the saved fuel efficiently in the combustion process and gain the energy from that fuel. That simply was the basis for our assumption in the fuel savings calculation. I think you can see immediately that there's a lot of question as to whether that's a valid assumption.

Mr. Winkler: This next question is from J. R. Sexton of Texaco: "You commented that compliance for meeting stage 1, filling underground tanks, and stage 2, refueling of vehicles, can be accomplished earlier in some regions where there is less concentration." I don't know that I said concentration. What I meant was where there is a lower concentration of gas stations, and I was talking more particularly about the Texas region. There is an explanation of this in the November 6 *Federal Register*.

The question goes on: "Since you mentioned earlier 90% emission reduction during refueling will not become effective until 1977 because problems are greater, I would assume you refer to development or technology in available equipment. It would appear that technical problems would be the same for areas of high or low density population. I would appreciate your commenting on this matter further, particularly since the impact on rural areas will

probably be greater than that on urban areas, with that requirement for earlier compliance in less populated areas." With regard to the few areas that were going to comply, or try to comply, before 1977—again, Texas—I can only assume that the regional office in cooperation with the oil companies and the operators and the state air pollution officials have arrived at reasonable dates. I would have to refer you to the regional office that prepared this particular date.

Mr. Walters: We'll try to take perhaps two more questions. Then Mr. Scott here, before you all break, has a couple of announcements. I would just like to remind the panel that we probably would like to get the questions back and copies of your talks and slides, Mr. Martens?

Mr. Martens: I've got one long detailed question, and I would like to sneak in an answer here for free, if you will, with a generality. The question really is since we "endorsed"—or, I'm sorry—"indicated a preference for the RB and W-Tokheim refueling emission control system," and on and on. In answer to many of the detailed questions, we have not evaluated that system. We only expressed a preference for, or endorsement of the concepts embodied, inasmuch as it seemed to embody the basic requirements to do this job in the best possible way.

Now, a specific question: "Assuming advanced tailpipe emission controls (circa 1975 and beyond)—including catalyst aftertreatment, integrated fuel metering, possibly with oxygen sensor or feedback, and the like—do not your objections to increase CO production and its attendant need for auxiliary vapor carburetion and/or air bleed composition control largely disappear?" Then the last part: "If the regional concept of emission control is appropriate for vehicle refueling, is it not also appropriate for tailpipe emissions?"

In answer to the last one, my personal feeling would be yes, it is. Regarding your question of advanced fuel control systems, I think as you look at the concepts that are being discussed in the literature for the so-called closed-loop oxygen sensor fuel metering system, certainly you can visualize that they would go a long way toward the solution of the problem of exhaust interaction of our basic evaporative emission control system, as well as the additional load a refueling emission control system might impose. It has the potential, certainly. At this point in time its potential has not been demonstrated. I think that's the best answer I can give.

Mr. Walters: I think we've run out of time for questions and answers. As you will note on the program, we're going to summarize these various sessions tomorrow afternoon.

Mr. Scott: I'd like to thank the speakers and certainly Don Walters for a job that I consider very well done indeed. Thank you.

TUESDAY AFTERNOON SESSION

INTRODUCTION BY THE GENERAL CHAIRMAN

I would like to introduce the afternoon session chairman, Mr. Robert Lunche. He is the Acting Air Pollution Control Officer of the Los Angeles APCD and certainly a man most capable of handling this afternoon's discussions. Bob, it is all yours.

CHAIRMAN'S REMARKS

Thank you, Bud, and welcome, all of you, to the King Arthur Room. I feel a little bit like the missionary who spent all day doing his thing in the African bush. When he came out, he was confronted by a lion. He looked around for a tree to climb; there wasn't any. He looked around for a river to swim across; there wasn't any. He looked for a clump of bushes to hide behind; there wasn't any. So he decided the only thing he could do was get down on his knees and pray. He closed his eyes, and he prayed and he prayed. Pretty soon he opened one eye, and there right next to him was the lion. The lion was also down on his hands and knees. As the missionary continued to look at the lion, the lion opened one of his eyes and spoke: "Well I don't know what you are praying about, brother, but this lion is saying grace."

If all of you have not said grace, you should, because you are about to receive some very interesting information about control technology for vehicle refueling. This is a subject dear to my heart and it brings back many, many memories.

I became interested in this aspect of air pollution back in the mid-Fifties. I can remember that at that time we made several false starts. One of them was in making specifications for a concentric hose to be used between the tank truck and the underground service station tank. In due time the hose was delivered and we started to use it. Of course we found it was so bulky (I think the outside diameter must have been about 8 or 9 inches) that the hose was impossible for the one man on the truck to handle. The hose was abandoned.

The second thing I remember is going out with Frank Bonamassa, who I think is here today, to look at a demonstration of an activated carbon adsorber being used for the recovery of vapors from an underground tank as it was being filled. As we stood watching this process, more and more smoke began pouring from that activated carbon. It wasn't long before Frank figured the problem out. What had happened was that the heat of adsorption for that small amount of carbon was such that the temperature of the vapors got higher and higher.

Anyhow, as you know from being here today, the process didn't stop there. A lot of things have happened since the mid-50's, and we are going to tell you about some of them now. We are going to begin with a presentation that is listed in your schedule as being given by Terry McGuire.

Since 1969, Terry has been with the Air Resources Board. He is presently Chief of the Implementation Section, which is involved with development of regulations for fueling vehicles. Terry?

REGULATING EMISSIONS FROM SERVICE STATION OPERATIONS—A VIEW POINT

by

Terry W. McGuire
Peter D. Venturini

Thank you, Bob. I will try to recognize my obligation as the immediate speaker after lunch, and not make any loud noises.

My presentation is basically an Air Resources Board staff viewpoint on the recovery of emissions from vehicle refueling. To date, one of the major sources of emissions of hydrocarbons which

is not extensively controlled in this state is the service station. These emissions now are perhaps 4% to 10% of the hydrocarbon emissions in a number of air basins.

It is, however, very probable that the emissions will continue to increase over the next few years if they aren't controlled. They must be controlled, first from the point of view that most other emission sources are controlled now, with the controls becoming more stringent because of the state implementation plan and the local regulatory programs. Second, at least if the energy crisis isn't as bleak as it may appear sometimes, additional volumes of fuel sold will compound this increase. This emission problem could grow to the point where, if the estimated level of emissions in the South Coast Basin were reached (the level whereby the National Ambient Air Quality Standard for oxidant would be achieved), the emissions from service stations could account for 20 to 25% of those emissions—all from one source.

The control of service station generated vapors fortunately falls into a class of control measures which probably isn't all that common right now. This effort is one of the few that not only have a pay-off in terms of reduced emissions into the air, but also provide a positive approach to the energy conservation problem. I will attempt to discuss, very briefly, some of the regulatory implications of this measure.

In general, the emissions statewide from service stations account for about 28 million gallons. That was the 1972 figure. Of those 28 million gallons, however, over 90% comes from the state's five most populous air basins; these being the South Coast, Bay Area, San Diego and the two big central valley basins. There are basically two sources of vapors, which we talked about a great deal this morning. These are the emissions associated with vehicle fueling itself and with the service station's underground tank.

As you can see in Figure One, the displaced vapors from vehicle refueling operations amount to about half of the emissions. The working losses of vapor displacement from the underground tanks are on the order of 40%. Losses associated with spillage and with breathing in the underground tank are on the order of 10%. The emission losses due to underground tank filling are now being considerably reduced through the use of submerged fill pipes. These reductions are on the order of perhaps 30% to 40%.

Several APCD's in the state, including most of those in the southern part of the state, have for some time now had regulations requiring all service station tanks to be equipped with permanent, submerged filler tubes. In addition, state law since the end of 1970 has required that all new service stations be equipped with submerged fillers.

Some of the regulatory considerations with regard to control of these emissions are found in the state implementation plan. The plan was adopted by the Air Resources Board at the beginning of 1972. That plan recognized a need to control emissions from service stations in the state's five most populous air basins. Since that time, the counties of Los Angeles, Orange, San Diego, and the Bay Area Air Pollution Control District have adopted new regulations dealing with this subject to one degree or another.

Last summer, the Air Resources Board adopted Revision 3 to the state implementation plan, which was more specific with respect to emission requirements in the Sacramento Valley Air Basin and the San Jacquin Valley Air Basin. Revision 3 provides that the districts, or some selected districts actually in those two air basins, are to consider for adoption by the first of next year regulations of this type. These regulations are to be effective by the beginning of 1975.

The staff has also proposed Revision 4 to the implementation plan, which will be considered by the Air Resources Board later this month. If adopted as proposed, Revision 4 would establish a similar timetable for the districts in the South Coast Air Basin. This timetable would ask for the adoption of the regulations by July 1, 1974, the regulations again to be effective at the beginning of 1975. Since the submittal of the first implementation plan, and even before, the Air Resources Board has followed and monitored the progress of these studies, watching and working with the American Petroleum Institute and those districts in this area that have adopted

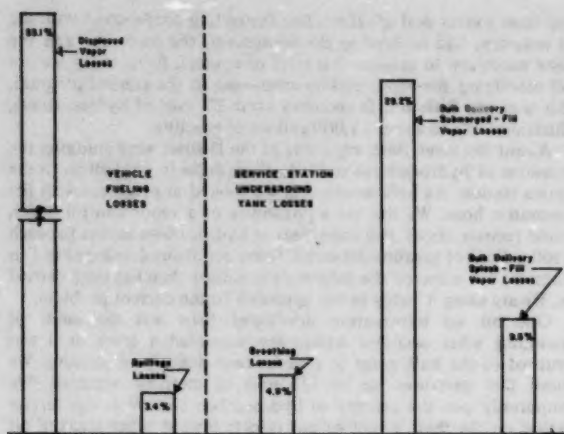


FIGURE 1: Breakdown of Vapor Losses from Service Station Operations.

regulations—particularly San Diego, which has had them for the longest period of time.

In developing the regulations, there are a number of basic considerations that will have to be weighed quite heavily. The first thing to be decided is the degree of control necessary in any regulation. Recognizing such factors as cost, effectiveness, and technical feasibility, we realize that if the specified degree of control is too low, there is the risk that air quality standards will not be achieved and maintained. On the other hand, too high a degree of control would have the effect of requiring expensive, complex equipment that would be burdensome to small operators. The regulations might also be more stringent than necessary. There will have to be a great deal of thought, I am sure, as to exactly how stringent the requirements should be.

Still another problem is the question of uniformity in test procedures and regulations. Take, for example, a performance requirement for an 80% or 90% control. We have as yet found no uniformly accepted test procedure for evaluating a system of this type. The presentation this morning from the Society of Automotive Engineers indicated, however, that we are moving along rapidly in this direction.

Furthermore, regulations within the state should be uniform. Such a standard would permit the use of the same equipment throughout the state. The various oil companies would then not be confronted with a situation in which one type of fitting is required in one county and a different type required in another county. A standardized system would also aid in the development of safety equipment. Other regulatory aspects dealing with the fuel pump, weights and measures, and so on would also be made easier.

In looking at emissions from the vehicle operation, we have this morning seen them broken down into two major areas, the service station storage tanks and the vehicle fueling operation. With regard to the vehicle service station storage tanks, as I mentioned a moment ago, losses are principally working or displacement losses. Breathing losses, although somewhat smaller, are still significant.

To date, the technology that is available for controlling these emissions ranges from the simple vapor displacement or vapor balance approach up through the more complicated and accordingly more effective methods of reconstituting the vapors—systems such as compression, refrigeration, and adsorption. The development of control regulations in this area would certainly require a great deal of consideration being given to such factors as the extent of vapor generation, the degree of control achievable by the various systems of vapor balance or the more complicated systems, and finally the cost and availability of hardware needed for the various types of systems. The cost would, of course, be figured on a production basis and not an experimental basis.

Moreover, some consideration may have to be given to the possibility of exempting certain very small, low-volume service station operations where controls would be very costly and at the same time would not really effect significant reductions in emissions.

In order to make the best use of the initial production of this type of hardware, we might make these regulations effective first in those areas where air pollution problems are most severe. The second area of vapor emission problems, of course, is that associated with vehicle fueling. As we learned earlier, this area is perhaps the most complicated and difficult to control. Losses again are made up of the displacement or working losses and spillage losses. The technology available for control of vehicle emissions seems divided into either the onboard vehicle control system (such as the adsorber cannister) and the service station type controls which would also be vapor balancing or the transporting of the vapors back to the underground tank, to the tank truck, or perhaps ultimately to the bulk plant. Perhaps there could be some reconstituting system at the service station itself.

One of the thorniest problems in this area is going to be the interface between the service station and the vehicle. Regulations dealing with service station vehicle refueling operations must be concerned with the various filler neck and external venting configurations that are on existing vehicles. The safety aspect is particularly significant here, I think, as well as the degree of control achievable by various techniques, the costs, and the availability of production-type systems. Again, these controls would undoubtedly be most effective if implemented first in areas where the problem is most severe.

In conclusion, I would like to say that the implementation of uniform, statewide regulations, excluding those basins where controls may not be necessary or appropriate, could significantly reduce hydrocarbon emissions and at the same time conserve at least modest quantities of fuel, which is in such short supply nowadays. Thank you.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you, Terry, for setting the stage.

I would now like to explain the upcoming portion of our program. We have with us panelists from the four agencies in California which are perhaps most conversant with vapor control and vehicle refueling problems. I will introduce each panelist and following their presentations, we will welcome questions from the audience or from the panelists themselves.

The panelists are Ray Skoff from San Diego APCD, Ed Camarena from Orange County APCD, Jim Talbot from the Bay Area APCD, and Bob Murray from the Los Angeles County APCD.

CONTROL DISTRICT EXPERIENCES PANEL I. Mr. Edward Camarena

Thank you, Mr. Lunche. This morning, we heard several people mention the concept of a regional approach to the air pollution problem. In following this philosophy, the Orange County Air Pollution Control District has generally patterned its rules and regulations after those of the Los Angeles Air Pollution Control District, our immediate neighbor to the north—after, of course, looking first at our own situation to determine whether these rules and regulations are needed and whether they would be effective in Orange County.

Orange County's program to control gasoline vapor losses began more than 6 years ago. In 1967, we adopted rules and regulations requiring gasoline vapor recovery systems at all major bulk loading facilities in Orange County. This rule alone has prevented the emission of about eight tons of hydrocarbons per day into the atmosphere. The regulations adopted in 1967 also required submerged fill tubes in all of the gasoline storage tanks. There are about 1700 service stations and well over 6,000 gasoline storage tanks in Orange County, all of them now outfitted with the submerged fill tube. Here we effected a reduction of about six tons of hydrocarbons per day, making a total control of 14 tons per day. This program reduced the emissions due to distribution of gasoline from 34 tons per day to 20.

The District has proposed additional rules, which were considered at a public hearing held by the Orange County Board of Supervisors on November 28. Decision on these rules has been continued until December 11 in order to give the District and other interested people an opportunity to examine the information that is being developed. The proposed rules would require greater control of gasoline vapors lost during the transfer from the truck tanker to the underground storage tank. They specify criteria for a balance system, but allow the user the option of any other system which has been determined by the air pollution control officer to be at least equally efficient.

Since September of 1972, the District has conducted numerous tests in cooperation with equipment manufacturers, some of the major oil companies, and the Los Angeles APCD. These tests have also been witnessed by representatives of the Bay Area APCD and the Air Resources Board. Generally, the tests have shown that a system such as the one specified in our rule—with a 3-inch vapor return to the tank truck, a half inch orifice on the vent, and submerged fill tube—will collect more than 90% of the vapors normally escaping from the vent during the transfer of gasoline from truck to underground tank.

In developing these rules, we were interested in the overall effectiveness of the controls. We paid particular attention to the reliability and efficiency of collection under realistic conditions. The requirement of the half-inch orifice not only will encourage the vapors to return back to the truck, but also will insure that the truck operator connects the vapor return line to the truck. Without this measure, we foresaw some considerable enforcement problems. If the truck operator should fail to make this vent connection, pressures would develop in the underground tank. These in turn would restrict the flow of gasoline and substantially increase the time required for delivery.

The proposed amendments to our regulations also require that the delivery truck receiving the vapors be refilled only at a bulk loading facility, where the vapors can be processed by a vapor recovery system. The system as proposed in our rule is compatible with any of the other systems we have looked at for vehicle refueling emissions. Some data we have recently been made aware of seem to indicate that a balance system could also be effective for the control at the nozzle, but we have not verified this point. The District, however, does intend to propose a rule early in 1974 requiring the control of vapors at the nozzle. This move will be in compliance with the State of California Implementation Plan for Achievement of the National Air Quality Standards as currently revised, and with the EPA transportation strategies that have recently been promulgated.

I think it would be well to take a look at what these emissions are in relation to emissions from other sources in Orange County. Our emission inventory indicates that emissions of hydrocarbons from all sources in Orange County total 477 tons per day. Twenty tons of these emissions currently are from the marketing operation and represent 4.2% of overall hydrocarbon emissions. If it were not for existing rules which control gasoline vapor loss, these emissions would be 34 tons rather than 20 and would constitute 6.9% of all hydrocarbon emissions.

A recently proposed rule would provide further control during the transfer from the truck to the underground tank and should reduce emissions to 14 tons per day, making them only 3% of the total. When we have control at the nozzle, emissions will be reduced to about two tons per day, making them less than 1/2 of 1% of the total. All of these figures are on the basis of 1972 emission data.

II. Mr. Robert Murray

We have been asked to comment on the experiences in the histories of our districts as far as vapor control goes. In Los Angeles County, we have to go back some 17 or 18 years to begin discussion of our concern about vapor losses from marketing or handling of gasoline products.

In 1956, the Los Angeles District focused its attention on the marketing of gasoline by implementing certain controls at the bulk loading facilities. We required that those facilities handling over 20,000 gallons of gasoline per day have a control operation that recovers over 90% by weight of the hydrocarbons involved. This

step took a great deal of effort. The District, in conjunction with the oil industry, had to develop the equipment, the hardware, and the plans necessary to achieve this level of control. Even today we are still modifying the vapor pickup arms used in the control program. This was our Rule 61. It recovers some 33 tons of hydrocarbons, which amounts to about 11,000 gallons of gasoline.

About the same time, engineers of the District were studying the emissions of hydrocarbons resulting from delivery of gasoline to the service station. As Bob mentioned, we looked at programs with the concentric hose. We did see a possibility of a vapor control which would recover about 180 cubic feet of hydrocarbon vapors for each 1,000 gallons of gasoline delivered. Some problems developed in this program, but some of the information gained then has been carried on. We are using it today in our approach to the current problem.

One bit of information developed then was the merit of examining what occurred within the vapor-laden truck as it was returned to the bulk plant to load its next delivery of gasoline. We found that pressures up to 1/2 inch of mercury occurred. We temporarily put the priority of hydrocarbon control at the service station on the shelf, directing our efforts toward other areas of air pollution control. It wasn't until 1961 that we focused attention on these matters again. This time, the program was much more elaborate. We were evaluating an interlock valve, the purpose of which was to achieve vapor pickup during the delivery of gasoline. As a result of this program, we found that the pressure dropped and the weight of the interlock valve indicated problems.

Other information developed from this program proved very interesting. We found, for example, that on a weight basis, some 37% of the hydrocarbons that would normally be evolved through splash filling of the underground tank could be controlled by effecting a submerged fill. We also found that about 93%, by weight, of the hydrocarbons that would normally be directed to the atmosphere on splash fill could be controlled by providing a vapor return of proper size back to the tank truck. All of these figures were in relationship to loading temperatures and volumes experienced under the test program. This work led, I think, to the first regulation in the country for the control of hydrocarbon at service station. This regulation requires a submerged fill at almost all of the service stations in the District.

In Los Angeles County alone, that rule has so far required that more than 25,000 tanks to be equipped with submerged fill tubes, representing a total capacity of over 100 million gallons of gasoline. According to our calculations, the second phase resulted in some additional 25 tons of hydrocarbons being prevented from entering the atmosphere.

In 1972, the attention of the District was focused on the remaining hydrocarbon emissions from gasoline marketing operations. A program was necessary, because of the requirement in the implementation plan to achieve state and federal ambient air quality standards. Representatives and manufacturers of service station hardware, inventors, and persons connected with the oil industry were becoming increasingly involved in this final phase of control of air pollution from gasoline marketing.

In October 1972, the District's task force on hydrocarbon emissions invited the Western Oil and Gas Association to form a joint task force, comprised of District and oil industry representatives, to develop a new regulation. The goal was more effective control. The task force studied such items as filling line sizes, vapor line sizes, temperature of the gasoline delivered and retained in the underground tank, quantities of gasoline delivered, the delivery rates, and pressure drops. We also studied such items as cost, equipment availability, classes of tanks, their capacity, and their use. Finally, there were the legal points. We needed a rule that did not require literally hundreds of inspectors to enforce.

We concluded that a 3-inch diameter vapor return line was optimum. Gasoline delivery rates were maintained. Pressure drops were encountered that resulted in essentially all displaced vapors being directed back into the tank compartment that was being emptied. Differences between the temperatures in Los Angeles County and along the coast were found to be in the 1-to-6 degree range. In this temperature range, there appeared to be minimal or no vapor growth.

The committee solved the problem of enforcement by requiring a half-inch restrictive orifice on the tank vent. A vapor line connection would transfer the vapors back to the tank truck. Should the driver or others involved fail to perform properly, loading time would be so restricted that the truck driver probably

would be at one location twice as long as he normally would. As mentioned this morning, there was also some discussion of the need for a dry-break coupling. This device could be functional, although there is a question of excessive pressure drops in some systems.

In view of all of this information, the District, in June of this year, amended Rule 63, which previously required only submerged fill tubes. Now the rule requires provision of a vapor control system for the distribution of gasoline to the underground tank. We feel that this regulation will be about 95% effective. It should control an additional 30 tons of hydrocarbon vapors.

For those who like to review cost figures, we estimate the cost of implementation to be around \$6 million. To convert the gasoline delivery trucks so that they can have the vapor returned to them will itself cost 3/4 of a million dollars. Our rule requires that tanks of 6,000 gallons capacity or greater must be controlled by May 1, 1975, the remaining vessels a year later, on May 1, 1976.

Regarding fueling control, the District is planning to propose a rule to the Los Angeles County Board of Supervisors. This will probably be done in the first part of next year. Two forms of this regulation are under consideration. Both require a 90% by volume efficiency. They will affect the transfer of gasoline to any motor vehicle, boat, or aircraft of greater than five gallon capacity. Filling from 250 gallon tanks or smaller and fueling of instruments of husbandry are exempt. Our effective dates under this proposal are for those vehicles that are fueled from 6,000-gallon tanks or greater, with a compliance date of September 1, 1975. For smaller tanks, the date is a year later.

We are also considering, as those who have read the recent rules promulgated by the EPA know, exclusion of vehicles that have filler neck configurations and locations or other car design features that would make a vapor-tight fill impossible.

Before closing, perhaps I should comment on the amount of vapors involved. Currently, hydrocarbon emissions from Los Angeles County, assuming that the tanks have only the submerged fill, amount to 116 tons per day. The comparative figure for the Southern California Air Basin is 168 tons. Approximately 35 weight percent of these hydrocarbons fall in the photochemically reactive category.

Projection of gasoline consumption—without rationing—to 1977 on the basis of the federal government's estimate of 4½% increase per year indicates that these potential losses would also increase. Los Angeles County would climb to 135 tons per day, while the Southern California Air basin would go up to 196 tons per day. With effective controls in all phases of gasoline distribution, however—controls would by then be required, according to our compliance schedule—over 120 tons of hydrocarbons would be prevented from entering the Los Angeles County Atmosphere, and over 175 tons from the South Coast air basin.

Another way of presenting this figure is to say that some additional 40,000 gallons of gasoline would be available per day—a worthwhile amount in today's present energy crisis. Thank you.

III. Mr. James Talbot

Mr. Chairman and ladies and gentlemen, the Bay Area Air Pollution Control District is an aggregate of nine counties in the metropolitan San Francisco Bay region. The total land area in its jurisdiction is 5,600 square miles, with 4.6 million people and 2.7 million automobiles.

We utilize the permit system for review of new construction. We are one of the few districts anywhere to use land-use control to implement such reviews. For example, we must deny permits for facilities that would cause ambient air quality to be exceeded on either federal or state standards. For vehicle refueling, however, an amendment states that we may not withhold such a permit if facilities are shown for a 90% recovery of emissions in refueling.

As all of us know, the facilities necessary for refueling emission control are under very active development at the present. Our staff feels that the dispensing nozzle is the most critical item in this development. This development, however, cannot progress until the remainder of the system is defined. We believe that the so-called forced displacement system of emission recovery is the minimum facility which will permit progress. We are presently granting conditional approval on such construction permits.

Our field experiences with the displacement system are limited,

but encouraging. Its feasibility appears to depend on two items—one, whether return vapor line resistance can be kept below a few-tenths inch water pressure in a vehicle tank; and two, definition of permissible interface connections. These questions will be answered by future development work, of which this seminar is a valuable part. Thank you.

IV. Mr. Ray Skoff

I do not have a very formal presentation, and I encourage you to ask any questions you might have as we go along, if that is in order with the chairman.

Before discussing the recent experiences of the San Diego Air Pollution Control District, let me briefly restate our Rule 63 for the benefit of those who might not be fully aware of what it really includes. Rule 63 requires that all vapors associated with the transfer of hydrocarbons must be vented to a vapor disposal system which must have a 90% recovery efficiency.

The wording of this rule is very well chosen. It states that all vapors must be vented, which is clear, concise, and enforceable. Had it stated that a certain percentage of the vapor had to be captured, it would have been necessary to determine what constitutes 100%. That is quite a difficult task, when we are talking about such volatile fluids as gasoline. Furthermore, if considerable vapors are detected during transfer—perhaps exiting from the half-inch vent line—how can we determine if that amount of vapor constitutes 10%, 5%, 20%? The vapor has already escaped into the atmosphere. To recollect the vapor and determine to the satisfaction of a court that the vapor exceeded allowable limits is an impossibility.

Therefore, the San Diego District interprets its rules as follows: if the vapors are not detectable either by the eye or by an electronic device, one can say that the vapors are not escaping. Accordingly, the District has secured several portable flammable gas detectors, which can easily detect 10% of the lower explosive limits, or .12%. I think we can say with good conscience that if we have less than 1% of hydrocarbons in the air, there are none emitted during the transfer operation. The device is small, weighs only a few pounds, and is only about 6-by-8-by-3 inches. It has a 6-foot long hose, which is used as a "sniffer" so that the operator can get to inaccessible areas or around filler necks and other obstacles.

The transfer of gasoline into delivery tankers, as has been testified to repeatedly, is no major problem. The tight connectors are available. They are being made by several manufacturers, and standardization of a certain size seems to present no difficulty. Three inches seems to be favored.

Refueling of cars is a different story, because we do have several filler neck sizes, although they do not vary anywhere nearly so much as one would tend to believe from the discussions here. A person could go down to Sears or any automotive parts supplier and say he needed a filler cap for his car. You would be amazed at how few sizes there are. We find small variations, mostly involving the locking device, but there is little difference in the diameter.

The location of the filler necks and a lack of concern by the attendant (and the general public), who will not fully insert the nozzle, will present a problem for some time to come. The District decided about a year ago that using a vacuum assist or a slight vacuum to extract the vapors out of the tank, would be a reasonable and desirable approach to resolution of the problem.

During the past year, we have demonstrated that vacuum assist is a very reasonable and technically feasible approach. It resolves the problems of varying filler neck sizes, inaccessible locations, and operator negligence. In order to assure compliance with the rule, we first analyzed the applications in detail. We determined what blowers are used, whether they are adequate for the facility, what some of the piping is, and what kind of shut-off valve is used on the vapor lines.

After establishing that the design is reasonable, we allow construction of the control equipment by issuing an authority to construct. After installation, we run a fairly extensive test, which primarily determines the strength of the vacuum at the nozzle. The vacuum is to be on the order of .5 to 2 inches of water, which is not a very high vacuum. We use the explosimeter or the flammable gas detector to search for escaping vapors. We intend to supply our inspectors or field representatives with a vacuum gauge and a small adaptor so that occasionally they can measure vacuum to see

whether the units are operating properly. The vacuum must be available at the nozzle; if they are escaping, vapors can be detected with the explosimeter.

There have been, in the last year, about four different nozzle configurations which are in production and which are used in San Diego. Many more nozzle designs, patents, and ideas have been shown to us. The one that most of you are familiar with is from Atlantic Engineering or Intermark. This design uses a bellows and a flat interface between nozzle and filler neck. Then we have one from Enviro-nics which intentionally ingests much larger quantities of air, because the system is designed to reduce the concentration of hydrocarbons before entering the reactor.

Other nozzles such as the ones designed by Calgon and by Shell Oil Company all have essentially the design feature we favor—namely, a concentric tube around the tube which dispenses the fluid. Both tubes can be inserted into the filler neck. The additional tube gathers and extracts the vapors before they have a chance to leave the filler neck. This kind of arrangement has proven most successful during our tests, and some of the other manufacturers have had the same results.

One of the problems associated with gasoline transfer is spillage. Several tests have been conducted by us, Mr. Davis, and other organizations. We found that if an attendant totally depends on the nozzle to shut off automatically, spillage is substantial. One out of five cars which are fueled and one out of three cars which are topped off have spillage. We find that during the time when gasoline was cheap and no concern was given to ecology or natural resources, spillage was very common. I have to confess that whenever I filled up my car, I felt that I had to get in the last drop. My car happens to be the kind which, given one more squirt after the automatic nozzle has shut off, spills most of the additional gasoline on the ground. There are problems which do exist, but which can be rectified more by education than anything else. The vapor recovery nozzles now being used, however, are a great help in that they ingest this spilled liquid and eventually return it to the ground tank rather than spill it out on the driveway. I would like to note here that during the time when service stations were limiting their customers to 10 or 12 gallons, I did not see a single drop spilled for over an hour.

In conclusion, I would like to state that a number of concepts and inventions for vapor recovery nozzles were presented to the District. There also seems to be considerable hardware available, when we consider that less than a year ago vapor recovery nozzles were almost unheard of. What is lacking is not so much the hardware, but a real, genuine cooperation in this area to resolve the remaining problems. Not all problems are solved in a first attempt at something new. Some of our problems lie in the material of the bellows used on some of the nozzles. In other cases, the automatic shutoff needs to be improved. These areas require further work. But if we could get the kind of cooperation on these problems that other industries have experienced on theirs—if those who are the major users of this equipment would support equipment designers and manufacturers who have been in the business for a year or six months—then solutions could be found.

One of the manufacturers related the following incident to me. He said that when he went to Kodak and DuPont and told them he had an answer to their vapor recovery problems, they investigated and agreed to give him money to support his work. Together they resolved their problem. When he approached some of the major oil companies, however, he was told simply to design and build the equipment. The oil companies would test it, and if they liked it they would buy it. I think we need a little more of the former type of cooperation. Thank you.

DISCUSSION PERIOD

MR. LUNCHE: Thank you, Ray. I think your presentation is certainly going to elicit some comments and requests.

We have heard from the air pollution control districts in California, but this is not the only part of the country having control districts or air pollution problems. In the audience today we have members of control districts from across the country.

I understand that Mr. Karas from East Chicago is here. Mr. Taylor is here from Colorado, Steve Weiner from Colorado, Mr. Hawk from Nevada, Mr. Jackson from Arizona, J. J. Alexander from Virginia, D. B. Anderson from New Mexico, D. H. Filbert from

Maryland, and W. H. Phillips also from Maryland. Gentlemen, we appreciate your coming from so far away.

Now we come to the questions. Again, I would ask that you go to the microphone and identify yourself. If you can direct your question to a particular panel participant, please do so.

MR. DONALD LANDRUM: I am with the State of Maryland. I would like a little more explanation on the vent throttle that you people use, or the pressure vacuum vent that you have on the vent lines for underground tanks. Is this device meeting with the approval of the Underwriters Laboratories? Who has to certify the tanks and determine the discharge size for these vents?

MR. CAMARENA: At this time, we have had no indication that the vent throttle device will not be approved. Later this afternoon, some representatives of the National Fire Protection Association will discuss the fire safety aspects of the controls we have developed. Hopefully, your question will be more fully answered then.

During our tests, we did have representatives from the Fire Protection Agency and from some local fire protection agencies in Orange County and Los Angeles County. They seemed to be satisfied with the orifice. Our device is not a pressure vacuum vent or valve. We have constructed on the top of the vent an orifice with a half-inch opening. Perhaps Mr. Murray could elaborate.

MR. MURRAY: The only point I might make is that the Los Angeles County Fire Marshall and Los Angeles City Fire Department have examined the operation's purpose of the restricting orifice and feel that it does comply with the requirements of the National Fire Protection Association.

As Ed has mentioned, I don't think there has been a formal commitment or statement from the Association. But inasmuch as these representatives feel that the device met their interpretation of the rule outlining tank venting, we did not necessarily feel obliged to obtain formal approval.

MR. SINGH BAJWA: I am from the Washington D.C. Bureau of Air and Water Quality Control. I have some further questions on this half-inch orifice. First, why was a half-inch orifice selected instead of a vacuum vent? Second, I would like to know whether your regulations require dry-break seals on your return lines. If they do not, why not?

MR. MURRAY: Concerning your question regarding the half-inch orifice, we did examine the pressure vacuum vent valve. I think the main point of contention was that the operation of this vent valve was not always acceptable. A second objection was that the valve did not really achieve one of the main purposes of the restricting orifice—to force the vapor line to be connected. In other words, the vent valve would still open perhaps by half an inch, by one inch, or by whatever amount the designed pressure called for.

To achieve what we feel was a 50-percent reduction in the unloading rate, we needed something between three or four pounds pressure. This type of valve would probably be much more expensive, perhaps with more problems than the simple orifice.

We examined some systems that do incorporate a dry-break. Use of a dry-break, though, introduces additional pressure drop in the system. We had some indication that the pressure drop addition versus the loss of the amount of vapor between the truck valve and the exit where the dry-break would be located was not sufficient to require its installation. The pressure drop problem would probably decrease the effectiveness of the vapor transfer back to the unloading compartment. It is still possible, however, that some dry-break valves that would eliminate the pressure drop problem will become available.

MR. CAMARENA: I have some additional comment on the half-inch orifice. From the enforcement standpoint, the orifice makes checking of sources to determine compliance easier. The orifice is here to stay. In Orange County alone, there are over 6,000 gasoline storage tanks which have to be checked. To have to check a valve on each one, as far as the pressure settings go, would be quite a task. And then the various parts of the valve would be changing over a period of time. We would much prefer a simpler system with fewer moving parts which would greatly ease the enforcement of requirements. Since it works, why not use it?

MR. SKOFF: I have a question both for Ed and Bob concerning this problem. If I understand you correctly, you are depending primarily on the tanker driver having a desire to complete the filling operation as rapidly as possible. If he is not so motivated, he could leave the vapor line off, with the only penalty being a loss of time. Is that correct?

MR. MURRAY: Well, aside from the lost time, there is the penalty of being in violation of the regulation.

The driver would almost certainly be found out in one of two ways. First, he could be caught actually leaving the vapor line off during refueling. Second, he would be suspected and questioned if he were to begin taking twice as long at his deliveries. An overlong delivery time would be made known by the time clock on his rig, and I am sure his supervisors would question him accordingly.

I think that the vapor line does force the issue onto the truck driver, but we feel that this is one problem he can handle and that we can be satisfied with the result.

Mr. Lunche: I would like to ask Mr. Skoff a question. After hearing his presentation, I think that quite clearly there is a difference between the system advocated and used in San Diego County and the systems that some of the other counties want.

The San Diego County APCD apparently wants to go to a higher collection basis. Accordingly, I would like to ask whether San Diego County has made any estimates of the additional amount of hydrocarbons prevented from entering the atmosphere and what the cost for that additional amount is. Is the additional amount that they get significant and economically worthwhile?

MR. SKOFF: We have made a number of studies, but I think we have to recognize one thing. Our implementation plan does not, even with the stricter regulations which we have, meet the EPA requirements. (Of course, we blame everything on Orange County and Los Angeles, which let all that stuff drift down south). But really, we are simply not able to meet the EPA requirements.

To be specific on the question of cost-effectiveness, I would ask you to recall one of the earliest presentations here this morning. I think Mr. Winkler indicated that vapor recovery is probably the most cost-effective method of all, other systems being considerably more expensive. I think we all wonder whether there really is that much gain by getting the additional percentage. Again, I think we must look at the overall picture. The overall problem of total hydrocarbon emission control is bigger than any single solution we have. In comparison to other control strategies in all the other industries, including hydrocarbon control, total hydrocarbon control at the service stations is the best and simplest way to go.

MR. BERNIE WEIDENAR: Arco. I would like to know what Mr. Winkler's cost-effectiveness figures were based on. Were they direct displacement or vacuum assist?

MR. FRED WINKLER: As far as I know, the figures included both Stage 1 and Stage 2 recovery. I think we did include vapor assist, that is, an auxiliary unit aside from just the vapor return on Stage 1 and Stage 2.

MR. DICK BURR: EPA Stationary Sources, Durham. I worked up some of the cost figures. My figures did not include any of the cost of recovering the vapors returned to the loading rack, and that cost is appreciable. In some respects, we lack the cost data necessary to make a good estimate.

The cost ratio is higher, but there is still a lot of work to be done. We included Stage 2 in two different concepts, the canister and the Intermark type system. The fact that our results were based on the API paper studies, however, should be recognized. They afforded the only data we had for input at the time.

We evaluated the canisters at around \$4,600 installed or \$6,000, which includes the cost of digging up the pavement. The refrigeration cost was figured at around \$12,000 including the off-the-shelf cost plus operating costs and other items. We have the numbers available. The cost of regeneration is in the carbon canister case. Again, we used API cost data. I am sure that as a result of this meeting, we are going to have better input for realistic cost calculations and cost-effectiveness calculations.

MR. SKOFF: I have been studying the original API report. We have been intimately involved in the conversion cost for some of the stations. If anything, the cost actually experienced in San Diego County has been slightly less than what API estimated.

Apparently, the county knew what it was doing. There is no excessive increase in the installation cost. Many of the units are below the price originally estimated by API. The figures used in the report are in the general area of the cost. If I remember correctly, API used on the order of \$5,000 for a recovery system and about \$7,000 for installation. The cost of recovery systems for San Diego are running between \$3-4,000 for some of the smaller units, with installation costs running on the order of \$2-3,000. Some of these costs are considerably cheaper, but I am talking about the average installation.

MR. LANDRUM: I have another question for Mr. Skoff, also dealing with this half-inch orifice. I would like to mention an EPS promulgation for Maryland that deals with gasoline transfer vapor control. The regulation concerns a vapor return line from the storage container to the delivery vessel and a system that will insure that the vapor return line is connected before gasoline can be transferred into the container. My question is, does the half-inch orifice suffice for this requirement? If not, what do you have in mind to insure that this hose be connected before the drop is made?

MR. SKOFF: We do not have this half-inch requirement. We do not think that the half-inch requirement is an adequate control. I am not familiar with that EPA requirement, but it will not meet our Rule 63, nor 61, which involves storage.

The half-inch opening would be on the underground tank as well as on the truck. During inbreathing or outbreathing, or filling or emptying of the ground tank, there is going to be some breathing in either direction. We do not think that the regulation you mention would be an adequate control. I really don't know how it would fit into the EPA requirement.

MR. LUNCHE: Maybe we ought to try some of the other panels who do have that particular element in their regulation. Jim, do you have that requirement in the Bay Area?

MR. TALBOT: At present we do not have any requirements for restriction on the vent line. I would like to add something. It occurs to me that the Eastern people have a considerably different problem from the one we face in California. The four districts represented at this table seldom see any frost. With the more extreme temperatures in the East, such a system could very easily freeze up.

MR. LUNCHE: Ed or Bob, do you want to answer this question concerning the orifice?

MR. CAMARENA: EPA's intent, as we understand it, is to assure that the system is connected. We believe that the half-inch orifice certainly meets the intent here, so our opinion is that the orifice does comply with the EPA requirement.

MR. RAJWA: In the District, we do not have the same interpretation as Mr. Camarena. We feel that the dry-break system is the answer to the problem. With the half-inch orifice, the cap of the return line can be open and still not connect the return line. The operator is still able to make the delivery. A half-inch orifice system is nullified by that flaw. Furthermore, the system is not operable. We must have some working combination, which will make that half-inch orifice operable as well as foolproof in meeting the requirements that EPA intended. At least, this is the District's position at this time.

MR. LUNCHE: Thank you. Is there someone here from EPA who can lend his interpretation of the rule to this discussion? Dick Burr is here, and Don Walters. Do either of you wish to comment on this question?

MR. DICK BURR: Actually, we are not literally interpreting what is required. Dick Penna could help me out here. The eventual enforcement of these regulations and the type of equipment to be installed will be up to Los Angeles County and San Diego County. We are seeking agreement between their interpretation of the law and our own. Dick, am I right?

MR. DICK FENNA: I think what we are going to require in any event is that a local jurisdiction come up with a regulation and submit that regulation to EPA, which will fulfill the promulgation. We are going to sit down and make some sort of technical judgment as to whether any particular regulation is going to suffice as soon as it is given to us by Los Angeles County, San Diego County, or the others.

MR. BURR: I think Jim Talbot made a valid point. There are problems with systems in some part of the country that do not exist in the Los Angeles area. In writing our regulations, we try to take this fact into account.

MR. HARRY HAINES: Haines Associates in Houston. I just wanted to ask the gentleman from EPA whether the wording is identical in all of the EPA regulations issued by New York, New Jersey, Colorado, and others—including California? On the point of not transferring the gasoline until the vapor return connection is made, is the wording the same in all of those Phase 1's.

MR. DICK FENNA: It should be, yes. Again, the regional offices put the plans together. We checked them for consistency of wording, and unless we slipped up in checking, the answer is yes, except for those regulations in Texas. The difference between regulations everywhere else in the country and in Texas lies in the

compliance dates. But as far as the actual wording is concerned, I think it is pretty much the same.

MR. AL PERCY: Union Oil, I would like to address a question to Ray Skoff. I have made numerous trips or pilgrimages to San Diego since the first of the year, and I generally have to buy gas somewhere coming or going. I have made it a practice to stop at competitors' stations down in San Diego, putting the bill on my Master Charge so the owners can't make quite so much money on me.

They are using a control unit which you have since approved. Yet while stopped there, I can always either detect hydrocarbon vapors with my nose as they come out of the fill nozzle, or see a puddle of gasoline left on the ground. I can't help feeling that this is one of our communication problems. How do you justify approval of such a system?

MR. SKOFF: I think we must recognize first of all that the nose is a much more sensitive instrument than most of the electronic instruments we have on the market today. You can detect, with the nose, parts per million—in some cases, parts per billion—of contaminants. Most of you have experienced this sensation. You detect some faint smell somewhere at the other end of the room. If we were to use the nose as judge of whether or not hydrocarbon vapors are escaping, I think we would have to shut down all the gas stations and every other facility that ever dispensed gas. An unfamiliar smell is easily detected with the nose.

The puddle or spillage is a problem not aggravated by the use of vapor recovery nozzles in most cases. In some cases, insertion may cause some spillage. Spillage is one of the areas I referred to in which further work needs to be done. I may have skipped over that section too rapidly. Two of the recent designs incorporate an extension of the nozzle—about an inch—so that the automatic shut-off is inserted further into the filler neck. This causes considerable reduction of spillage.

These are areas that need improvement.

I would be most surprised if all the answers were found in the first six months. That would really be asking too much. Spillage has been a customary problem at all gas stations for 20 years and has never been satisfactorily resolved. To expect to resolve the problem in six months or a year is not very realistic.

MR. LUNCHE: We have time for one more question.

MR. GORDON POTTER: Exxon, out of Houston. Mr. Skoff, we appreciate the logic of a vacuum system to avoid leakage at the nozzle and at other locations. Certainly the basic concept is logical. We have, however, a very serious concern due to the many variables that occur during the process. We are afraid that fuel not flowing immediately or having a tighter seal than intended might, by drawing air into the vent of a pre-70 car, create an explosive mixture within the vehicle tank. We think that to expose our customers and the public to this kind of hazard without very thorough testing would be totally unrealistic. What is your view?

MR. SKOFF: Well, I think that you will find it nearly impossible—at a vapor concentration of 30-to40% hydrocarbon concentration by volume in a tank—to extract vapors at such a rate that they cannot be replaced by evaporation of the gasoline to stay above the explosive limit, which is on the order of 7%. You would have to extract vapors very rapidly, for a considerable length of time.

Remember you are talking about a nearly empty tank to start with, at least not a completely filled tank. So, you are talking about a fairly large volume. The vacuum applied is quite small and would not have the flow rate necessary for potentially explosive conditions. Last but not least, several of the designs, notably that of Calgon, have taken into account the possibility of producing a vacuum; if there is no flow the mechanism sucks in air at a side port. This kind of bypass arrangement is quite satisfactory and will preclude any of the dangers you are referring to.

MR. POTTER: I am not familiar with the Calgon system, but we have tested other equipment and have definitely demonstrated an explosive mixture within the tank. If air comes in the vent line at the interface, of necessity there must be an explosive mixture at that interface. The question is how large. If flow from the pump doesn't begin immediately and the valve is open, we are very concerned that the result could be a significant amount of explosive vapor. Until we have far more demonstration that we are in fact operating safely, I question any requirement that we should make such an installation.

MR. SKOFF: With reference to your statement that there is an

explosive mixture at the vent, you are quite right. It is exactly the same thing which happens when you drive your car down the street. You are sucking out gasoline and sucking in air. At some point or another, zero hydrocarbon concentration goes through the explosive range and then finally you are in the tank with the fully saturated vapor. But that is, as I say, no different from the conditions you have normally when you open up the filler cap. If you were to have a fire, you would have a fire. Whether it is a little or bigger fire, it is still a fire.

MR. POTTER: One last question. How do you see our position relative to other regulations, such as codes which require Underwriters label approval and that kind of thing? We are not, as I see it, meeting those standards.

MR. SKOFF: The question of UL and OSHA approval has been brought up at various times. We have been in contact with these agencies for some time and have received different answers, depending on interpretation. I think most of you are aware that the law is frequently interpreted differently by different people.

Specifically, interpretations vary on questions of the nozzle, whether it should have a hood or some other adjunct added to it and so on. Whether or not these variations represent changes to the basic requirements of UL has not been clearly stated. The OSHA requirements state that a nozzle must meet certain criteria. I am not sure I can remember all 10. The regulations require such things as that the nozzle automatically shut off as it drops 20 inches to the concrete floor. There must be a poppet valve capable of holding 10 psi. There are four or five other requirements pertaining to the liquid flow.

These requirements are not changed by the nozzles being used. We don't have the authority to interpret OSHA law. But judging by our discussions with OSHA, we do not envision a very complex or involved problem in getting approval of the nozzles with any modifications being made to them to get vapor recovery.

INTRODUCTION BY THE SESSION CHAIRMAN

The second part of our session this afternoon will be directed by Norm Schell of the San Diego County APCD. He is nationally accredited in the comprehensive practice of industrial hygiene and has been in the field of environmental engineering since 1947. He is presently the Deputy Air Pollution Control Officer for the County of San Diego. Norm?

INTRODUCTION BY SESSION VICE CHAIRMAN

Thank you, Bob. San Diego County is very happy to be able to participate in this seminar and conference. I believe that when our sponsors asked me to assume chairmanship this afternoon, they wanted to make sure I heard every word that our speakers have to say with regard to requirements other than those of air pollution control.

I am looking forward to our speakers who will be commenting upon two areas in which you have already raised questions. I hope that as occasion arises, you will restate those questions for the gentlemen who are perhaps most familiar with these areas. I will introduce both of these gentlemen at this time, and then they will speak individually.

As you know, in this afternoon's meeting we are discussing some areas which are not concerned with air pollution control, per se. We will concern ourselves with safety requirements and consideration of weights and measures. Many of you have expressed some apprehensions in these areas. I want you to know that the County of San Diego is also concerned about these matters. We have spent some time looking into them.

I would now like to introduce to you Mr. Miles Woodworth. He comes to us with a great deal of experience in the Fire Protection Association. At the same time, I would like to introduce Mr. H. E. "Tiny" Sandel. I asked him what name I should give, and he said all his friends would recognize him by the name of Tiny. Mr. Sandel has served for some 30 years with the Department of Weights and Measures in San Bernardino County. I am sure the experience of

both these gentlemen qualifies them to speak on their respective subjects. Without further ado, I ask Mr. Miles E. Woodworth of the National Fire Protection Association to address us in his subject area.

PRESENTATION OF THE NATIONAL FIRE PROTECTION ASSOCIATION

by
Miles E. Woodworth

Thank you very much, Mr. Schell. The National Fire Protection Association was organized over 77 years ago to promote the science and improve the methods of fire protection and prevention. One of its first objectives was to develop standards in the field of fire protection. For example, our first standard dealt with the design and installation of automatic sprinkler systems. Today, every automatic sprinkler system installed in the United States complies with NFPA standards.

With regard to the public, you probably have been exposed to our educational materials on the prevention of fires. As the sponsors of Fire Prevention Week, for over 50 years we have attempted to educate children as well as adults on the importance of preventing fires in the home as well as in places of work. During this year's Fire Prevention Week, we distributed over 15 million pieces of fire prevention educational materials.

The NFPA currently has a membership of approximately 30,000 from more than 89 countries. Today, many of our 200-plus fire protection standards are either adopted into law by foreign governments or are used by them as standards of good practice. Here in the United States, cities, counties, states, and many branches of the federal government adopt our standards into laws or regulations. The most recent adoption of NFPA standards was made by the U.S. Department of Labor under the Occupational Safety and Health Act, which already incorporates over 50 NFPA standards.

With this introduction to the goals and purposes of the NFPA, I would like to discuss with you some of our concerns in the areas of fire prevention as related to air pollution control measures. Certainly we share your concern for cleaning up the air. Pollution control is a subject which affects all of us. We ask only that when considering methods which can be and are being used to remove air pollutants, some effort be made to insure that the particular method employed does not create a fire hazard.

We have, for example, been receiving an increasing number of fire reports in which the cause of the fire was burners of various types used in incinerating pollutants which are being discharged to the air. Combustible residues are incinerated as they are discharged into the atmosphere, but the residues can also collect on the inside of the duct. The open flame then serves as a source of ignition and the residues are ignited, causing a fire which can flash back into the building.

There probably is an answer to this problem, either through some other method of removal of these pollutants or through a difference in design or controls for such burns. In any case, such equipment, particularly if it incorporates a burner, should be tested and listed by a nationally recognized testing laboratory.

I might add that last week I was at one of our NFPA committee meetings in Atlanta for two days developing standards on dip tanks. The same committee that revised our standard on spray finishing expressed concern about this fire hazard. Many plants are utilized these burners on the exhaust duct from paint spray booths. Friday of last week, in Chicago, another committee met on dry cleaning. Here again the committee members expressed their concern over some of the air pollution control measures. On Wednesday and Thursday of last week an industrial safety group met in Des Moines, where several questions concerning air pollution control measures were raised.

Now, let us discuss some mutual potential problems which center on service stations' prevention of hydrocarbon vapors from escaping into the atmosphere during delivery to an underground tank or to a vehicle. First, I understand that during delivery from a tank vehicle to an underground tank, you are proposing to fill the

tank from a hose with a tight fill connection. Another hose will return the displaced vapors from the tank back to the tank vehicle.

This may well be a safe procedure. Our only major concern is that during this transfer operation, no undue pressure be exerted on the underground tank. This concern can be easily put aside by conducting pressure tests during filling operations for the different locations and sizes of tanks. I should also mention that the tight-fill connections are sometimes known for not being so tight. The reasons for this failure are varied, but they include a lack of maintenance.

A second problem during the filling operation involves the driver who frequently fills the tank and then has a hose full of gasoline after shutting off the valve of the tank vehicle. Particularly when the station is closed, he may remove the nozzle from the fill pipe and simply drain the excess gasoline into the ground around the fill box. Literally dozens of cases involving this practice have been reported as the cause for gasoline getting into the ground, where it causes a water pollution problem, a fire hazard, and severe damage to underground electrical and telephone equipment.

The NFPA has a flammable and combustible liquids code—NFPA No. 30—which has been adopted by over 40 states, numerous counties, and more than 2,000 cities. In addition, the U.S. Department of Labor has adopted most of the code in the OSHA regulations. In our code, there is a chapter on service stations which covers in considerable detail the many requirements for construction and equipment that make these stations reasonably safe from fire.

Most regulatory officials require that the gasoline dispenser, hose, and nozzle be tested and listed by nationally recognized testing laboratories such as Underwriters Laboratories. I have already seen at this meeting what I would consider several violations of this type of equipment. Generally speaking, the average service station uses an automatic nozzle with a latch opening device. On the other hand, self-service gasoline stations are required by the NFPA code to have an automatic nozzle without a latch opening device.

I have heard, as I mentioned, the proposal which would exhaust the vapors from the dispensing operation through a special connection to the fill pipe back through a special hose around the fill hose. I am concerned that these special connections and the special hose may affect proper operation of the nozzle. One answer to this problem would be a test of the entire assembly, which would then be listed by a nationally recognized testing laboratory.

In this regard, I should mention that the gasoline dispenser itself, whether it be the conventional type or an overhead dispenser, is required to be approved as a unit. I saw one drawing this morning which I think might violate good practice as far as returning the vapors to the dispenser. Again, I must emphasize that if we use such a device, the system should be tested and listed by a nationally listed testing laboratory. Any change to the dispenser, therefore, would require that the entire unit be approved. Another area of concern for us lies in the installation of any electrical device in or around any gasoline liquid or vapor space. Our code specifies this area as a classified area in accordance with the national electrical code, whether it be class 1, division 1, or division 2, or an ordinary location. Reported, not only refrigerated equipment, but also other electrical equipment designed for ordinary locations has been installed in class 1, division 1 or 2 areas.

Any blower installed in a vapor recovery system should meet the standards of the NFPA for blower and exhaust systems, regarding handling of flammable vapors. This includes the motor as well as the fan itself. An additional concern of ours would be the increase of gasoline vapors into the flammable range. Formerly, the gasoline vapors in most closed containers have been too rich to burn or were above the upper flammable limit. There are several possible sources of ignition, including electrical or static sparks, which could cause a fire or explosion if the vapor space above the liquid is brought into the flammable range.

Another possible area of concern for older tanks would be adding connections to the tank for the new vapor lines if there were not enough existing connections. The hazards of cutting holes or welding pipe connections to a gasoline tank are quite apparent. I might add that fiberglass reinforced plastic tanks, I understand, do not have the usual five connections. Even though you would not be doing any cutting or welding, the lack of connections does mean providing special fittings for these tanks. In the future, I believe, the tanks will have more vents.

Venting of underground tanks during filling operations has

always been a major concern to us, because of the number of fire explosions resulting from improper venting. The code specifies the size of the vent, which can vary, depending on the length of the vent pipe, and specifically states that the vent shall discharge vertically. The table which we have in the code relates itself to a gallonage not to exceed 2.5 psig on the interior of the tank. Most of the fires and explosions which have occurred resulted from vapor being discharged downward because of return bends being placed on the end of the vent line.

There have been various proposals that would restrict the flow of such vapors from vent lines. In a few proposals, the tank is seen as being under pressure through use of pressure vacuum venting devices. Since leaking underground tanks are creating a severe problem in the United States, this constant pressure can only lead to an increase in the problem. Incidentally, the EPA of New England has called me in two or three times now on their problems with leaking underground tanks or leakages from other sources, creating hazards underground. Any changes in venting regulations as currently contained within our flammable and combustible liquids code will need to be carefully reviewed by all concerned.

In summary, there are many proposals for vapor recovery in prevention of air pollution problems which may cause fires or explosions. On the other hand, prevention of the escape of vapors during fuel handling may reduce fire hazards, particularly if the unit is properly designed.

I wish to emphasize the importance of preventing conflict between air pollution control regulations and fire protection regulations. Such conflicts can create not only enforcement problems among the enforcement agencies, but also compliance problems for the industry being regulated. I can only offer you cooperation on behalf of the NFPA in minimizing these possible conflicts. Thank you.

**PRESENTATION OF
THE DEPARTMENT OF WEIGHTS
AND MEASURES AND
CONSUMER AFFAIRS
COUNTY OF SAN BERNADINO**

by
H. E. Sandel

Thank you, Mr. Schell. I am pleased to be here today to give you my thoughts on the consideration of weights and measures control as it relates to vehicle refueling emission.

For the benefit of those of you who might not be acquainted with weights and measures, I would briefly like to tell you some of our duties. Weights and measures is as old as time. From any study of early history, we learn that weights and measures regulations have been written into almost every moral code or law ever set down. Why? Because a system of weights and measures is fundamental in dealings between people, states, and nations.

California has been very active in the weights and measures field for the past 60 years. Here in California, weights and measures regulations consist of two codes. One is a business and professional code as it pertains to weights and measures, which is passed by the state legislature. The California Administrative Code, Title 4, includes those business regulations designed to improve administration of those laws which are enacted. You will also find that our Administrative Code, Title 4, is almost identical to H44, as adopted by the National Conference on Weights and Measures. All regulations in our Title 4 are adopted after administrative hearings, affording interested parties ample opportunity to debate whatever regulation is adopted.

Weights and Measures here in California is charged primarily with the responsibility for checking all commercial weighing and measuring devices. We are also concerned with several of the laws pertaining to packaging, the net contents concept, and petroleum products. As you can see, we have considerable responsibility in the marketplace. The primary objective of weights and measures officials has long been to see that equity prevails in all commercial transactions involving the determination of quantity. In other words, we strive to see that both buyer and seller receive full value.

The reason for my appearing on your program is to give you my views on weights and measures control, insofar as it pertains to vehicle refueling. We fully realize that there are many, many problems involving measurement confronting the petroleum industry and equipment manufacturers—as well as ourselves—in the weights and measures field. Proving methods and equipment, for example, must be altered or changed completely to conform to the system or systems that are now being tested. I am sure that many tests and experiments will be conducted before any definite conclusions are reached.

Our goal in this field will be to assimilate as fully as possible the use of the device being tested. Our test procedures probably will have to be revised after such systems are developed. Even tolerance considerations may become a factor.

At the present time, the Los Angeles County Department of Weights and Measures is revamping its retail gasoline pump-testing units. When completed, the air test unit will be a completely closed system, with no loss of vapors to the atmosphere. The 5-gallon seraphin test measure which has long been used in the testing of retail gasoline dispensers will be discarded. In its place will be a newly devised 5-gallon test measure conforming to all API, ASTM, and NBS recommendations. Weights and measures officials here in Southern California are anxiously awaiting the arrival of this new test unit so that we can see how it performs.

A second consideration of weights and measures control is the extent to which variations in vacuum or pressure will affect the accuracy of a vacuum or pressure type system. What safeguards are to be used to prevent liquid in the vapor line due to surge-back or overflow? What effects will temperature variations have on these systems? Will the system incur any difficulties in winterized gasoline, as opposed to summer fuel? Would a problem here make any difference in the flows test or providing vessel?

The final consideration of weights and measures controls concerns vapors. At the present time, all, or almost all vapors are going into the atmosphere. Yet, these vapors belong to both parties. Weights and measures officials are faced with the basic question: Who does the condensed liquid belong to and of what monetary value is it?

I would like to tell you about a test conducted by Santa Barbara and Ventura County on retail gasoline dispensers, using a 5-gallon seraphin test measure connected to a simple condenser. The investigators were consistently able to recover between 1/2 and 3/4 of a cubic inch of liquid per 5-gallon draft.

At the present time, there are several types of recovery systems proposed, none of which provides ultimate satisfaction in efficiency. But we can agree on one thing. The development of these systems is expensive, and the industry will have to bear the cost of vapor recovery systems. The individual user—whether he be the car owner, terminal plant operator, or service station dealer—should not expect adjustments for vapor recovery. The only difference, as I see it, in future operations as opposed to those of the present is that the vapors are not polluting the atmosphere.

As different systems are developed, consideration must be given to interlocks, anti-drain valves, and air elimination requirements. All have a decisive effect on the delivery of products. In summarizing my position as a weights and measures official, I strongly recommend that both the petroleum industry and the equipment manufacturers work closely with departments of weights and measures at national, state, and local levels.

Here in California, if a device in commercial use at the present time should be altered or a new device should be installed, such change would require type approval. If we all work together, confusion will be kept to a minimum. I want to assure you that regardless of which method of vapor emission control is finally adopted, weights and measures officials will be very interested in any problems you might encounter. We would like to be kept advised of the various systems under consideration. Above all, I want to assure you of our complete cooperation. Thank you very much.

DISCUSSION PERIOD

MR. SCHELL: Thank you very much, Mr. Sandel. I think these two gentlemen have given us many insights and have raised some very interesting questions. Either they or other interested

participants here will now have the job of answering those questions. At this time, we will entertain questions from the floor. Please address your question, if you will, to one of these gentlemen.

MR. SKOFF: I was wondering whether you issue actual permits or authorizations or whether you have a different form of showing approval or disapproval of a system.

MR. WOODWORTH: The NFPA does not approve or disapprove anything. We have certain standards, which any city, county, state, or federal agency may adopt. These agencies then become what we call an authority having jurisdiction. Are you talking specific equipment? If so, we rely very extensively on nationally recognized testing laboratories.

MR. SKOFF: Yes, I was referring to equipment. I was wondering whether you analyze the equipment, either drawings of or actual equipment, to check for compliance with your NFPA 30 or any other relevant regulations you might have.

MR. WOODWORTH: We would refer any approval of equipment to a nationally recognized testing laboratory for testing and listing. Frequently, we do get blueprints in. There is a question of interpretation of the code, but that is all. The committee

responsible does not attempt to approve these plans, nor do we decide any question of code interpretation relating to the plans.

MR. SKOFF: If I understand you correctly, the local fire authorities, then—the fire departments and so forth—issue their approval or disapproval.

MR. WOODWORTH: That is correct. As was mentioned this afternoon by representatives of the City and County of Los Angeles, if they interpret the code and approve a particular design, that approval is theirs alone. I might not agree with them.

MR. SKOFF: Mr. Sandel, do you have some sort of approval process in your department? If so, is that process a statewide or a countywide operation?

MR. SANDEL: The approval of devices is a statewide operation. You submit your particular device and ask the division of weights and measures standards to type-approve that device. Once type approved, the device is legal throughout the state of California.

MR. SCHELL: Do we have anymore questions? If not, we will consider this portion of our program concluded. Thank you very much.

WEDNESDAY MORNING SESSION

OPENING REMARKS

by
Carleton B. Scott

I think we should get started, gentlemen. We have a very tight schedule.

I would like to make one very brief announcement regarding some good news. You may recall that yesterday morning in discussing the objectives of this meeting, I mentioned that one of the things we really should do is try to obtain some guidance on how we might strive for compliance with these many regulations. Some of the regulations, as you know, are rather difficult to comply with. Last night I had the good fortune to be at the same table with a respected member of the California Air Resources Board at a time when he received clear cut evidence of this guidance. The message came from a very good source. It says, "Be true and trust each other and all will be well." This hopeful sign was found in a Chinese fortune cookie. Therefore, I feel we have a very good omen at this midpoint in our deliberations.

This morning we are going to hear about hardware and design concepts. The man who will chair this session is Bob Brattain. Mr. Brattain is a member of the California Air Resources Board. He is, in fact, former chairman of the Technical Advisory Committee for that Board. Bob?

INTRODUCTION BY THE SESSION CHAIRMAN

Good morning. Yesterday during the morning session, we concentrated on the various organizational viewpoints, with a couple of reports on actual research programs now in progress. During the afternoon session we discussed some of the problems we share. This morning, we will look at the actual implementation of systems designed to control air pollution and still meet official standards.

The gentleman that spoke for the API yesterday, concluding the morning session, mentioned that we had heard a diversity of viewpoints. I would like to disagree somewhat. I thought the presentations showed amazing unanimity. Everybody seems to think that refueling loss is an appreciable source of hydrocarbons. I don't think there was any disagreement on that. Everybody seems to think that there is a cost-effective way of reducing the hydrocarbons. The gentleman from the EPA said 10 pounds per dollar. There was unanimity on another point as well. Everyone agreed that somebody else ought to do something about the problem.

I think that we can learn some lessons from yesterday. There is no question but that we should discuss our problems. Yet, we should discuss our problems with a view toward their solution and not as an excuse for doing nothing. I might add, we shouldn't have all been amazed yesterday when we found out that there was a

cost-effective method. We have known of cost-effective methods at least since 1970, when proposals were made at a meeting of the Air Pollution Control Association in San Francisco. A paper given at that meeting by one of our speakers this morning, Mr. Gockel, calculated cost-effectiveness. I think that the only real criticism I have on the subject is that we haven't done something with this information in such a great length of time.

We also heard yesterday that one of the reasons we ought to get going now is that there are pollution controls being set on cars. We will have a greater incentive to effect such a method, because escaping fueling vapors will then be a larger percentage of the polluting hydrocarbon sources left. I think this is a completely fallacious argument. By the time we have achieved the kind of control that we hope to achieve on automobiles, there may no longer be any real reason to control this small amount of hydrocarbons. A relatively small amount of hydrocarbons will not become more necessary to control simply because that amount becomes a larger percentage. The real reason we ought to control refueling vapor is that this is the most cost-effective piece of hydrocarbon control we can implement.

Our first speaker this morning will be Mr. Leiferman of Chevron Research. He will give us the introductory presentation this morning. Our next speaker will be Mr. Decker of Emco, then Mr. Hansel of Sun Oil, Mr. McCrory of Gilbarco, Mr. Moore of OPW Division of Dover Corporation, Mr. Percy of Union Oil, Mr. Silver of Texaco, Mr. Cisco of Parker-Hannifin, Mr. Slawinski of Andrews Industries, Mr. Copony of Wayne Pumps, and Mr. Sutcliffe of Husky Corporation. Would you please start off, Mr. Leiferman?

VAPOR CONTROL CONCEPTS

by
M. W. Leiferman

I intend to describe briefly four basic concepts of vapor control systems for service stations. Then I will go into a little more detail on one of these systems, presenting some test results.

One concept, the one on which I will present some test data a little later, is a displacement or balance system. This system consists of piping which transfers expelled vapors from the vessel being filled back into the supply vessel. During vehicle filling, the vapor from the vehicle tank is transferred to the underground storage tank. During the storage tank filling, this vapor is transferred into the delivery truck or trailer. Vapors in the truck are then recovered at the loading terminal.

In addition to the displacement system is an adsorption system. The most common material being used in this application is activated carbon. A container holding the adsorbing material is installed in the underground tank atmospheric vent pipe. Hydrocarbons vented through this line are trapped on the adsorbing material. With this system, a blower can be used to maintain a

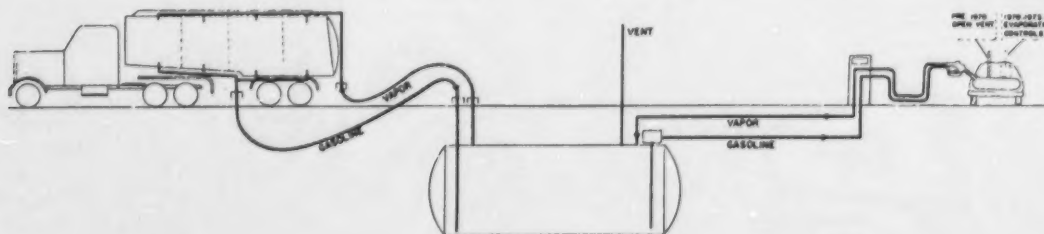


FIGURE 1: Displacement System.

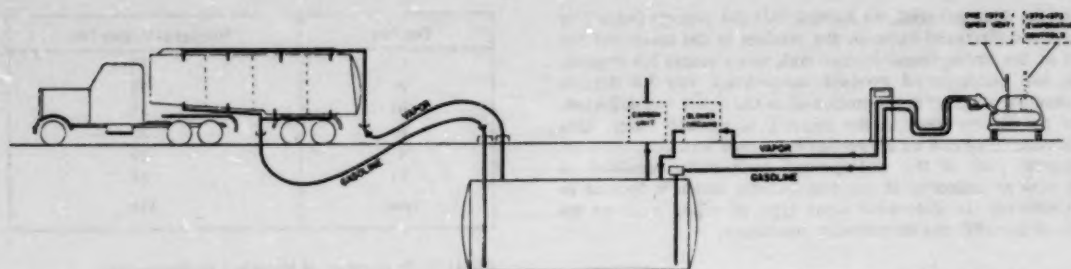


FIGURE 2: Carbon System.

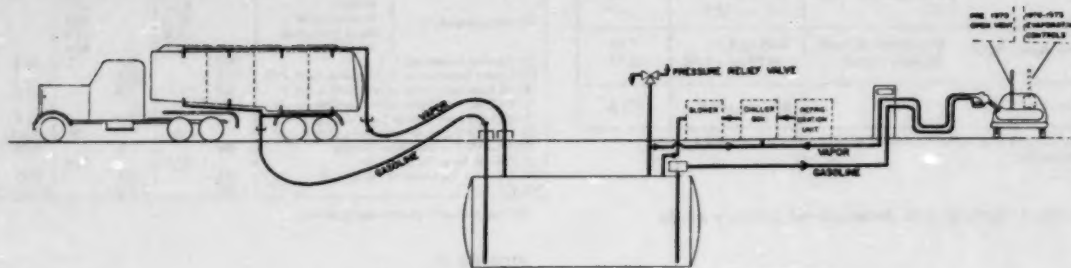


FIGURE 3: Refrigeration System.

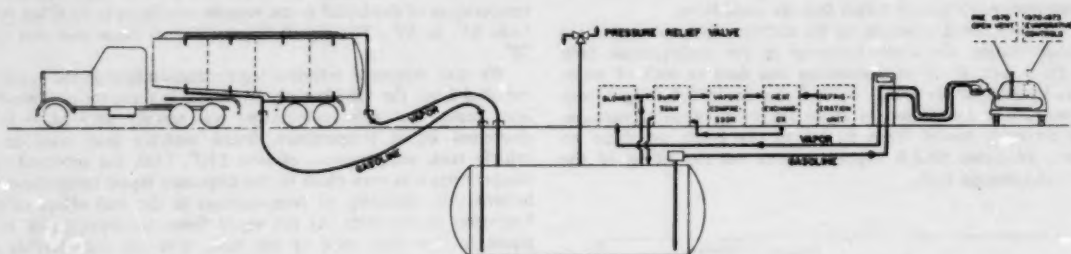


FIGURE 4: Refrigeration-Compression System.

vacuum in the vapor return line to the dispensing nozzle. This improves vapor recovery at the vehicle, even if a vapor tight seal is not achieved at the dispensing nozzle filler pipe interface. The system also enhances recovery on pre-evaporative control vehicles. When it has reached its hydrocarbon capacity, the adsorbing material must either be regenerated or replaced.

The refrigeration concept is a modification of and addition to the displacement system. Refrigeration is, in a sense, a closed system which is isolated from the atmosphere by an emergency release pressure vacuum valve. If a positive system pressure of a predetermined magnitude is reached, a blower then is activated, circulating vapors from the underground storage tank across coils of the refrigeration unit. Cooling of the vapors results in a pressure decrease and partial condensation of hydrocarbons, due to the lower temperatures. When the system pressure has been sufficiently reduced, the unit stops operation. If a vacuum of sufficient magnitude should develop in the system, air would be drawn into the preset pressure vacuum relief valve.

The refrigeration compression system also consists of additions to the basic displacement system. A blower is used to maintain partial vacuum in the vapor return system at the dispensing nozzle. Hydrocarbon vapors and any air drawn in the nozzle are returned to the underground storage tank. Any excess vapor volume is saturated and stored in a holding or surge tank. This vapor is eventually processed by various stages of compression and refrigeration. The condensate is returned to the saturating liquid in the holding tank and/or the underground storage tank.

I would like to go into a little more detail now and present some results from tests conducted with a displacement system. This study consisted of two parts: the first was a test on filling the underground storage tank; the second was a test on filling vehicle tanks. I would first like to talk about filling the underground storage tank.

For the first step in this study, we did a survey of actual temperatures at service stations during the underground tank filling process. To date, we have covered some 422 deliveries at service stations from ten terminals between San Diego and Seattle.

Number of Deliveries	ΔT^* Range, (°F)	Percent of Total Deliveries (%)
7	+10 and Greater	1.7
10	+5 to +9	2.4
22	+1 to +4	5.2
15	0	3.6
121	-1 to -4	28.7
167	-5 to -9	39.6
80	-10 and Less	19.0
Average	-3.8	

* ΔT = Temperature of Product in Truck (—) Temperature of Product in Underground Tank.

FIGURE 5: Summary of Temperature Distribution Survey.

From the data gathered, we learned that the average Delta Tier temperature differential between the product in the truck and the product in the underground storage tank was a minus 3.8 degrees. That is, the underground product temperature was 3.8 degrees higher than the product in the truck before the liquid was delivered. Most of the figures were in the minus-1 to minus-9 range. This survey is continuing and we are getting more numbers.

A second part of the underground tank study consisted of actually making deliveries at our test facility, which is located in Davis, California, to determine what type of vapor recovery we could get under different temperature conditions.

Data or Results	Range	Average
Temperatures, (°F) { Ambient Product Unloaded Underground Tank ΔT	65° to 100° 71° to 89° 74° to 84° -6° to +12°*	80° 80° 75° -1°
Pressures (in. H ₂ O) { Underground Tank Delivery Truck	0.05 to 0.76 -0.07 to -1.48	0.30 -0.72
% Recovery	92.2 to 100.0	95.6

*Product was artificially heated to simulate this temperature differential.

FIGURE 6: Summary of Underground Delivery Study.

Figure Six indicates that the Delta T's which were investigated in some 18 tests we ran up there varied from a minus 6° Fahrenheit to a plus 12° Fahrenheit. I, should mention that in the case of the plus 12° Fahrenheit figure, we had to heat the product in the truck, so this result does not simulate actual delivery conditions.

We also monitored pressures in the underground tank and in the tank truck during the drop. Pressures in the underground tank ranged from near 0 up to something less than an inch of water pressure. In the delivery truck, we had vacuums which ranged from again near zero to a maximum of about 1½ inches of water, vacuum. Percent recovery varied from 92.2% up to 100% on these 18 deliveries, averaging 95.6% vapor recovery on the filling of the underground storage tank.

Fill Conditions	Ambient Conditions	
	Warm (-80°F)	Cool (-60°F)
Insured Complete Seal	Part I - Evaporative Controlled Vehicles	Part IV Part V
	Part II - Non-Evaporative Controlled Vehicles	
Typical Operation	Part III - Nozzle Design A	Part VI - Nozzle Design B

FIGURE 7: Ambient and Filling Conditions for Vehicle Vapor Recovery Study.

In the vehicle filling studies, a test program was designed along these parameters. Essentially we did two groups of tests. One group was done in rather warm weather (about 80° Fahrenheit). The other tests were done at approximately 60° Fahrenheit ambient. We had three test parts in both the warm and cool ambient conditions. For each ambient condition we also tested two different conditions of filling. In the first two parts, we insured a tight seal at the nozzle-filler pipe interface. In the last part, we had a service station attendant actually do the filling, to determine how good a seal we were obtaining with the nozzle.

In the first group of tests, we had evaporative control vehicles in Part One and non-evaporative control vehicles in Part Two. Figure Eight should give you an idea of the number of vehicles filled during each part of the test, some 114 vehicles in all. These vehicles were chosen as being representative of popular makes and models on the road today.

Test Part	Number of Vehicle Fills
I	11
II	13
III	31
IV	22
V	20
VI	17
Total	114

FIGURE 8: Number of Vehicle Fills Performed.

Data or Results	Part I		Part II		Part III	
	Total Value	Average Value	Total Value	Average Value	Total Value	Average Value
(1) Temperatures, °F { Ambient Vehicle Liquid Dispensed Liquid Return Vapor	81.0 87.5 78.5 78.7		78.3 85.6 78.3 80.0		77.1 89.4 78.3 78.9	
(2) Gasoline Dispensed, F ₃	16.9		28.4		39.9	
(3) Vapors Returned to Underground Tank, F ₃	15.6		25.5		32.4	
(4) HC Loss from Underground Tank Vent, g	0.0		0.0		0.0	
(5) HC Loss from Evaporative Canister, g	1.5		—		—	
(6) HC Loss from Vehicle Tank Vent, g	—		50.3		12.8	
(7) Expelled Vapor, ft ³ /Dispensed Liquid, ft ³	—	0.87	—	0.96	0.81(1)	
(8) Total HC Expelled from Vehicle, g	467		778		1004(1)	
(9) Percent Vapor Recovery, %	99.7		94.4		—	
(10) Predicted Uncontrolled HC Loss, g	506		965		1447	
(11) (8)/(10)	0.783		0.806		Assume 0.80	

(1) This does not include losses at nozzles.

FIGURE 9.

Figure Nine is a temperature condition for test Parts 1 and 2. Ambients were running at about 80°, as I said earlier. Our temperature of the liquid in the vehicle coming in to be filled ranged from 85° to 87°. The liquid dispensed into these cars was about 78°.

We also measured returned vapor temperature as the vapor was expelled from the vehicle tank. We found in these tests, as we did in later tests, that this temperature was usually very close to the dispensed liquid temperature. Some vehicles that came in had vehicle tank temperatures of over 110°. Still, the returned vapor temperature was very close to the dispensed liquid temperature. We believe this similarity of temperatures is the real effect of what happened in our tests. As the vapor flows counter-current to the liquid in the filler neck of the tank, you get considerable heat exchange. That is, the vapor comes into equilibrium with the liquid.

As you can see in line 2, we have a gasoline dispensed volume in Parts One and Two. Below that we have a volume of vapors returned to the underground storage tank. In both Parts One and Two, the volume of vapors returned to the underground tank was less than the volume of dispensed liquid, meaning that, as shown by line 4, no vapors were expelled out of the underground storage tank vent line. I should mention that in all these tests the two-inch underground tank vent was left completely open.

In line 5 for Part One of the test, we measured the amount of hydrocarbons going out of the evaporative control canister under the hood of the car to the air cleaner of the car. All through these tests, we saw only 1.5 grams in total as being expelled from the evaporative control canister. This amount is really negligible.

In Part Two of the test, as seen in line 6, we measured the amount of hydrocarbons expelled from the atmospheric vents on the tanks. Since they were all pre-evaporative control, these cars had either vents which breathed directly into the atmosphere or went back into the filler neck of the vehicle and were vented there. In fact, about 40% of these vehicles were vented back to the filler neck. Concerning the vapor recovery process, these cars are for all practical purposes evaporative control cars and do not have actual atmospheric vents external to the filler pipe. We lost 50.3 grams of hydrocarbons out of the atmospheric vents on these cars.

An interesting ratio that we calculated was the expelled vapor volume divided by the dispensed liquid volume. We can see in Part One that the ratio was .87 and in Part Two, .96. On the average, then, in both cases less vapor volume was expelled from the vehicle tank than the liquid volume that was put into them. If we compare the figure in line 8 with the figure in Part 1 (the amount lost from the evaporative canister system) the result shows close to 100% recovery by the system. In Part Two, however, the 50.3 grams lost

out of the atmospheric vents amounted to 94.4% vapor recovery on these vehicles.

Another interesting project was to calculate the predicted uncontrolled hydrocarbon loss. The loss was calculated with work done by Scott Research Labs for the Coordinating Research Council in their CAPE-9-68 study. If we take this number and compare figures with the actual amount of hydrocarbons we observe being expelled from the vehicle tank (467 in Part One as compared to the predicted uncontrolled loss), we get a ratio of .78. If we do the same thing with Part Two, we get a ratio of .80. We have a fairly close agreement, then, in that the actual measured amount expelled from the vehicle tanks was 80% of the uncontrolled loss predicted by the CAPE-9 regression analysis.

HC Description	HC Quantity, g	Percent of Total Expelled HC, %
Total Amount Expelled from Vehicle Tanks	1158.1	100.0
Measured Amount Expelled from Vehicle Tanks	1003.5	—
Loss at Nozzle-Filler Pipe Interface	154.6	13.3
Loss Through Atmospheric Vents	12.8	1.1
Returned to Underground Tank	990.7	85.6

FIGURE 10: Summary of Results of Vehicle Filling Study—Part III.

Part Three of the test, as I mentioned earlier, was a little different. We did not insure a tight seal at the nozzle, and we had a service station attendant actually do the filling. In this case, when we get numbers of total expelled hydrocarbons from the vehicle, those numbers will exclude any amount lost at the nozzle-filler pipe interface.

What we wanted to know was the total amount of hydrocarbons actually expelled from the vehicle tank. The method we used was to calculate the predicted uncontrolled loss. Then, if we assumed 80% of that number, we would have the amount actually expelled from the vehicle tank. Our resulting figure was 1,158 grams. We measured about 104 grams coming out of the vehicle tank, indicating a

difference of 154.6 grams, which we believe were lost at the nozzle-filler pipe interface. This figure was about 13.3% of the total amount expelled from the vehicle tank.

In Part Three of the study, 12.8 grams were lost from the atmospheric vents, a figure amounting to just a little over 1% of the total expelled from the vehicle tank. The amount returned to the underground storage tank was about 991 grams, which amounted to 85.6% of the total expelled from the vehicle. In other words, we had an 85.6% vapor recovery, with the prototype nozzle being used under actual service station operating conditions.

Figure Eleven shows the vapor expelled volume, divided by the dispensed liquid volume. A graph of these ratios was plotted against the Delta T, which is the initial vehicle fuel tank liquid temperature minus the dispensed liquid temperature. As we go to the right hand side of the graph on the bottom axis, we see the vehicle tank temperature getting warmer than the dispensed liquid.

One thing we noted from this graph is that the difference between the evaporative emission controlled vehicles of Part One and the non-evaporative emission control vehicles of Part Two. The difference seems to be of the same population. As vehicle tanks get warmer, this ratio between expelled vapor volume and dispensed liquid volume decreases. We get a vapor shrinkage effect, in other words. As I mentioned earlier, we feel this result is due to the expelled vapor coming into equilibrium with the dispensed liquid in the filler pipe of the vehicle tank.

Parts Four, Five and Six of the study are very similar to Parts One, Two and Three, except that the former were done at cooler temperatures and that we used a dispensing nozzle in Part 6 different from the one used in Part 3. We wanted to evaluate the operation of the new dispenser.

Data or Results	Part IV		Part V		Part VI	
	Total Value	Average Value	Total Value	Average Value	Total Value	Average Value
(1) Temperatures, °F						
Ambient	61.9	64.2	64.2	69.2	69.2	69.2
Vehicle Liquid	69.3	72.5	72.5	63.2	63.2	63.2
Dispensed Liquid	67.1	67.6	67.6	67.6	67.6	67.6
Return Vapor	84.2	84.2	84.2	84.2	84.2	84.2
(2) Gasoline Dispensed, F-3	29.6	19.8	19.8	29.9	29.9	29.9
(3) Vapor Returned to Underground Tank F-3	26.2	18.4	18.4	24.6	24.6	24.6
(4) HC Loss from Underground Tank Vent, g	0.0	0.0	0.0	0.0	0.0	0.0
(5) HC Loss from Evaporative Control, g	3.4	—	—	4.1	4.1	4.1
(6) HC Loss from Vehicle Tank Vent, g	—	—	—	0.78(1)	0.78(1)	0.78(1)
(7) Expelled Vapor, n3/Dispensed Liquid, n3	0.84	0.84	0.87	0.87	0.87	0.87
(8) Total HC Expelled from Vehicle, g	664.2	664.2	467.8	506.9(1)	506.9(1)	506.9(1)
(9) Percent Vapor Recovery, %	99.4	99.4	100.0	100.0	100.0	100.0
(10) Predicted Uncontrolled HC Loss, g	845.6	845.6	571.5	716.7	716.7	716.7
(11) (8)/(10)	0.795	0.795	0.819	0.819	0.819	0.819

(1) This does not include losses at nozzle.
(2) Excluding 2 vehicles on which no vapor was recovered.

FIGURE 12.

Figure Twelve includes a total dispensed liquid volume and a vapor volume returned to the underground tank in Parts Four and Five. Again, these volumes in both cases are less than the total volume of dispensed liquid. We therefore assumed that here again no hydrocarbons were lost from the underground storage tank vent line during the tests.

If we look at the expelled vapor volume divided by dispensed liquid volume, we get ratios of .84 and .87. From these figures we can calculate the total of hydrocarbons expelled from the vehicle in Parts One and Two. If we compare the results to the small amount of vapor lost from the vehicle tank vent, we again find high vapor recovery percentages.

In these tests, we did not use a number of non-evaporative control vehicles which would be proportional to their percent in the total car population. Therefore, this result is not really a measure of how much vapor would truly get out of the atmospheric vents.

Interestingly enough, we can again calculate the predicted uncontrolled hydrocarbon loss as seen in the CAPE-9 study. Comparing that result to our measured hydrocarbon loss from the vehicle tank, we again came out with ratios of .78 and .82, figures which are very close to the conditions we found in Parts One and Two. The measured amount of hydrocarbons expelled from the vehicle tank was again approximately 80% of the predicted uncontrolled loss.

In Part Six of the study, when the service station attendant actually did the filling, we had a predicted uncontrolled loss of 716.7 grams. If we take 80% of that number (573 grams), which is the total hydrocarbons expelled from the vehicle tank during Part Six of the test, we find 507 grams being expelled. The difference in this case was only 66 grams, which represents the amount lost at the

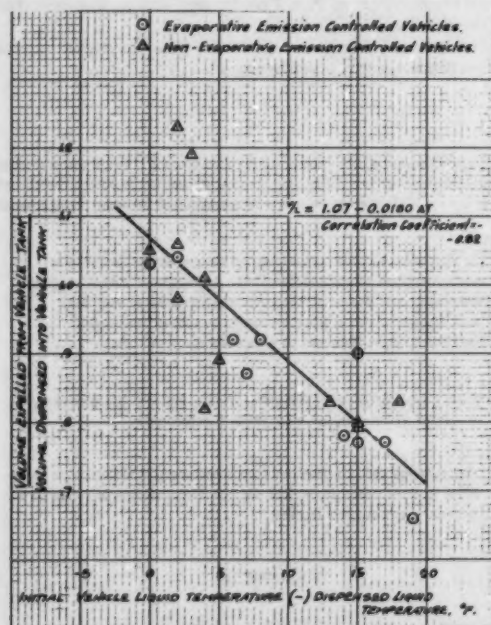


FIGURE 11: Relationship Between Liquid Temperatures and Expelled Vapor Volume in the Vehicle Filling Process.

HC Description	HC Quantity, (g)	Percent of Total Expelled HC, (%)
Total Amount Expelled from Vehicle Tanks	573.3 (513.3)*	100.0
Measured Amount Expelled from Vehicle Tanks	506.9	—
Loss at Nozzle-Filler Pipe Interface	66.4 (6.4)*	11.6 (1.2)*
Loss Through Atmospheric Vents	4.1	0.8
Returned to Underground Tank	502.8	87.7 (98.0)*

*Excluding two vehicles from which no vapor was recovered.

FIGURE 13: Summary of Results of Vehicle Filling Study—Part VI.

interface. This loss was 11.6% of the total hydrocarbons expelled from the vehicle tank. The total returned to the underground tank (502.8 grmas) amounted to 87.7% of the total hydrocarbons expelled from the tank. Our results show an 87.7% vapor recovery with this prototype nozzle in typical service station operation.

There were in this test two vehicle from which we recovered no vapors. One vehicle was such that, because of its filler neck configuration, the nozzle just would not physically go far enough in to get a seal. In the other case, the nozzle would have had to be hand held in order to get a good seal. So we recovered no vapor on these two vehicles. As a matter of interest, we had a 98% vapor recovery if we excluded those two particular vehicles from the test.

Again, for Parts Five and Four, this graph represents the return or expelled vapor volume divided by the dispensed liquid volume versus the same Delta T, shown earlier in Parts One and Two. As you can see in Figure Fifteen, a comparison of overall results allows us to make the assumption that returned vapor temperature comes into equilibrium with the dispensed liquid temperature. We can then predict a sort of theoretical value for what this relationship between vapor, liquid ratio, and Delta T should be. That value is shown by the dotted line on the graph. The slope of the experimental data varies, but results are quite close to the theoretical prediction. The spread in the experimental data may be mostly explained by the fact that because we did the filling at different ambient conditions,

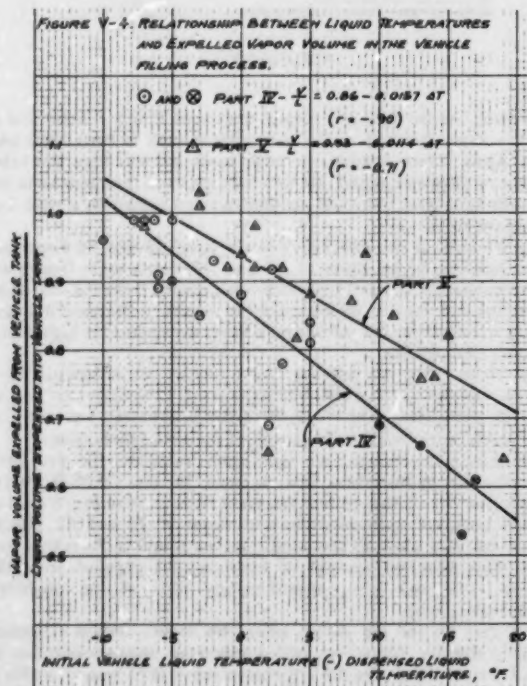


FIGURE 14.

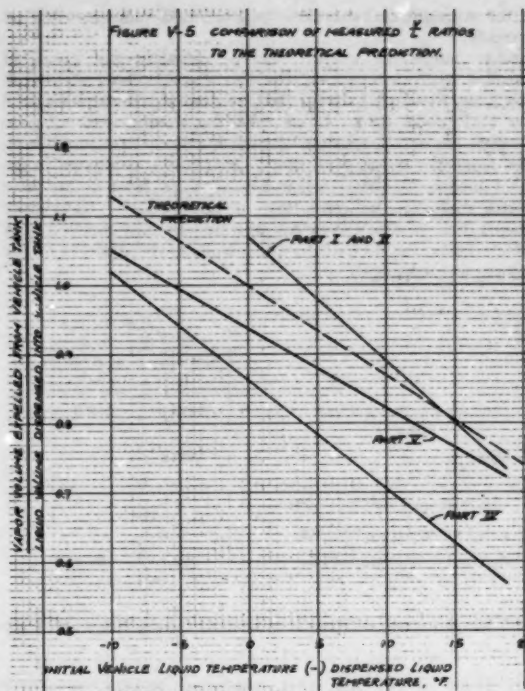


FIGURE 15.

we had to measure vapor volume by a meter in the vapor return line. By the time the vapor got to this meter, the vapor was very close to ambient temperature. When the ambient temperature happened to be cooler than the dispensed liquid temperature, we had some condensation in the vapor return line, resulting in some volume loss. In Part Six, the ambient was cooler than it was in part Five. Ambient temperature in Part Five in turn was cooler than that in Parts One and Two.

In conclusion, I would like to list for you the several important results we felt we got from our study:

1. Vapor recovery efficiency of greater than 92% is attainable for underground tank filling when the unloaded product temperature is up to 12°F higher than the underground product temperature.
2. During vehicle tank refueling, an excess vapor volume is not generated when vehicle fuel temperature is higher than the dispensed liquid temperature; when the initial fuel tank temperature is greater than the dispensed liquid temperature, a decrease in vapor volume occurs.
3. With a nozzle which seals effectively, vehicle fueling vapor recovery efficiency of over 95% is attainable.
4. An average vehicle fueling vapor recovery efficiency of over 85% is attainable in typical service station operation with a present prototype nozzle.

FIGURE 16.

I do want to stress the fact that these are present prototype nozzles. Of the two nozzles we tested, one gave slightly over 85% recovery efficiency and one about 87% recovery under typical operating conditions.

I would mention two additional results. First, the system would be at least 90% effective in controlling total hydrocarbon vapor losses at service stations with a present prototype nozzle. And second, a "displacement" system is more desirable than other types of vapor control methods in the areas of cost effectiveness, energy requirements, regulation enforcement, and time required for installation.

I hope that you gentlemen will find some of our test results useful in researching your respective fields. Thank you.

INTRODUCTION BY THE SESSION CHAIRMAN

Thank you Mr. Leiferman. We will now hear from those people who are involved with research on nozzles and fittings. The first of our speakers will be Mr. Decker of EMCO-Wheaton.

NOZZLES AND FITTINGS PANEL I. D. B. Decker

Good morning, gentlemen. Thank you, Bob. We are pleased to be able to present our line of vapor recovery and transfer equipment at this meeting today.

At EMCO-Wheaton, we made a decision in 1969 to apply some of our expertise in loading arms and vapor recovery equipment to vapor transfer systems. We decided that there were three problems not completely resolved. The first was at the terminal, the second involved dropping the product at the service station, and the third concerned actually filling the automobile.

As I stand before you today, we have solved problem one, we have solved problem two, and we are very close to solving problem three. Now, the problems and the way we approach them are detailed in a piece of literature to which you are welcome. It is called "Transfer of Gasoline Vapors and Petroleum Marketing

1. BOTTOM LOADING AT TERMINAL



2. UNLOADING AT SERVICE STATION



3. FILLING AUTOMOBILE TANK

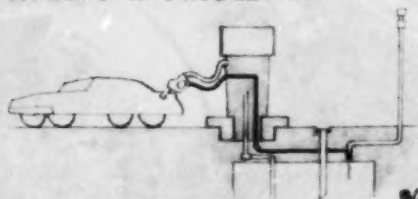


FIGURE 1: Vapor Recovery.

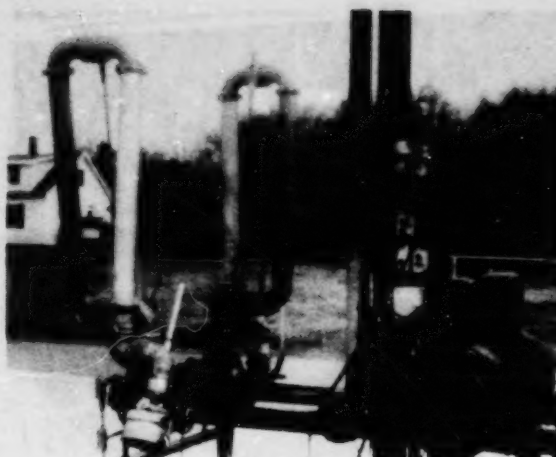


FIGURE 2.

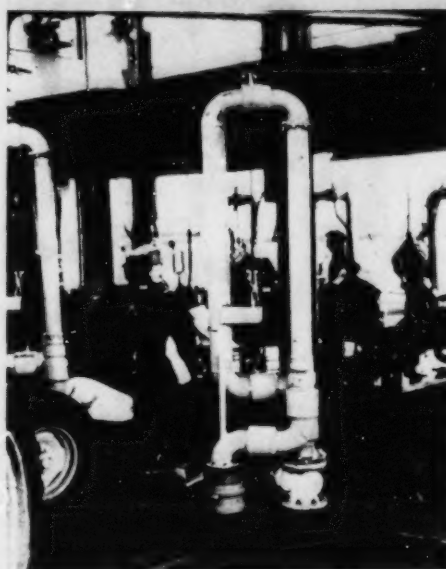


FIGURE 3.

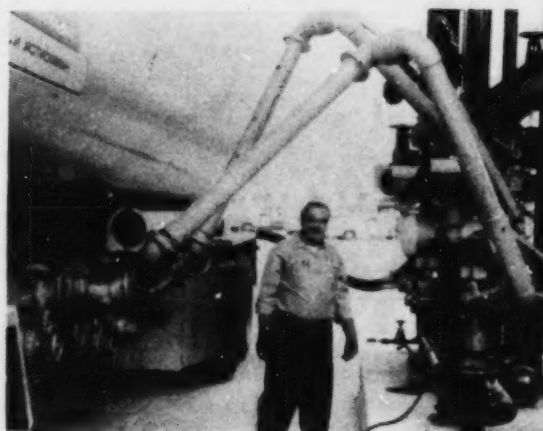


FIGURE 4.

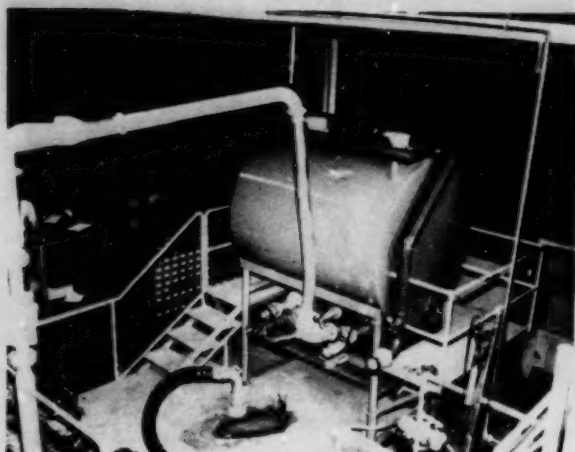


FIGURE 5.



FIGURE 8.

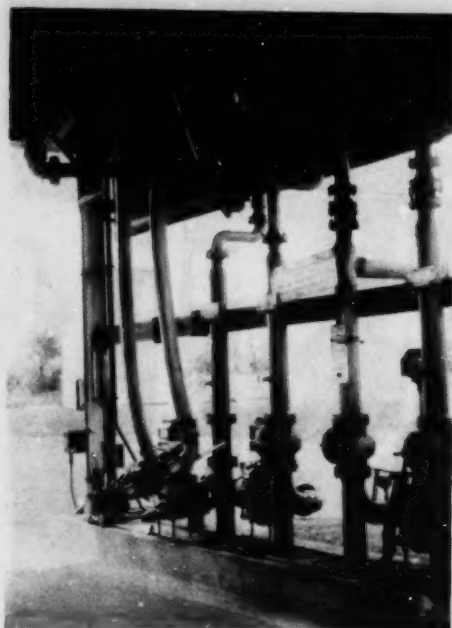


FIGURE 6.



FIGURE 7.

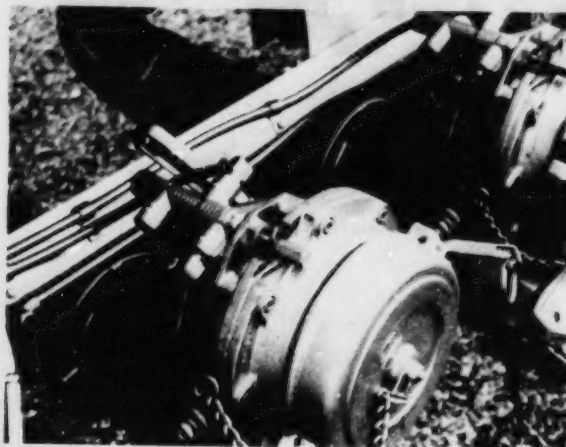


FIGURE 9.

Operations" These are available in our suite, and we would be glad to let you have them. We also have another piece of literature which details the systems at the service station which are associated with the drop of the product.

We are convinced that in the areas of vapor transfer and of control of hydrocarbons, bottom loading is part of the answer.

As you can see in Figure One we demonstrate bottom loading.

Figure Two is a bottom loading A-frame type arm located in a small terminal.

Figure Three is a similar piece of equipment that is located in a large terminal.

This is another picture of bottom loading, showing the operation of the arm when coupled to a transport.

Figure Five is another piece of equipment that we have developed, called a hose loader. The hose loader provides another method of bottom loading tank trucks. The device is installed in a test facility at our plant in Conneaut, Ohio. As you can see, we have simulated a tank truck with the vapor recovery equipment installed. We can run tests and make certain of accuracy.

Figure Six is another method of converting present loading racks to bottom loading. Our method is a very inexpensive one for taking the old style top loaders and converting them to bottom loaders.

This is our API coupler, which conforms to RP1004. The coupler gives us the great flexibility in production of equipment that is interchangeable. The independent hauler can now go into a terminal and be serviced with a piece of equipment, whether or not that equipment is produced by us.

Figure Eight shows our patented Y-valve which is used for the bottom filling and unloading of transport trucks.

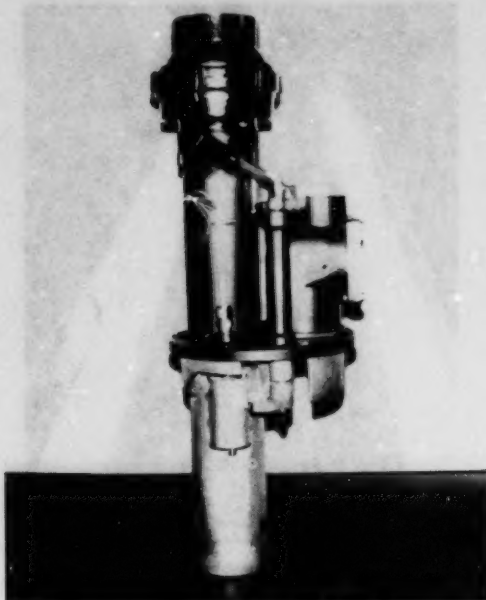


FIGURE 10.

Here we see the same valve upon an air interlock shown on the top. This device locks the brakes on the truck so the truck cannot move during filling.

We also realize the need for top vapor recovery loading arms. We have developed this piece of equipment (seen from various angles) which is currently in production. This device allows very inexpensive conversion from top loading to bottom loading.

These are various pieces of equipment that control the vapors and the emission of vapors, on tank trucks.

These are vents.

Here we see a conversion kit, designed for use on present trucks. Here is the same unit installed on a vent.

Figures Eighteen and Nineteen show two views of the unit installed on a truck.

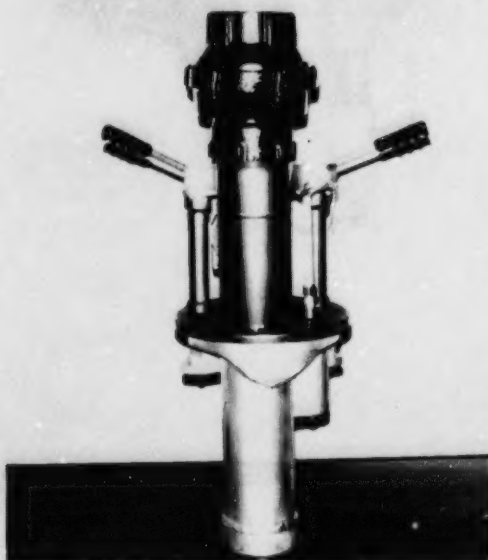


FIGURE 11.

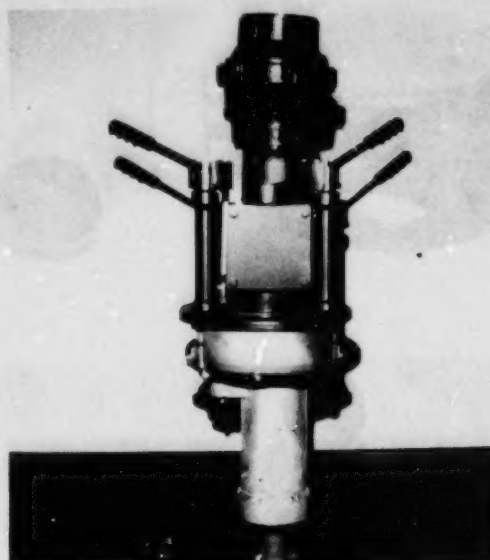


FIGURE 12.

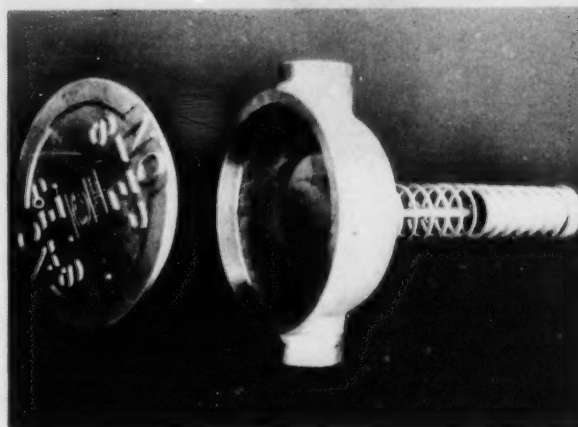


FIGURE 13.



FIGURE 14.

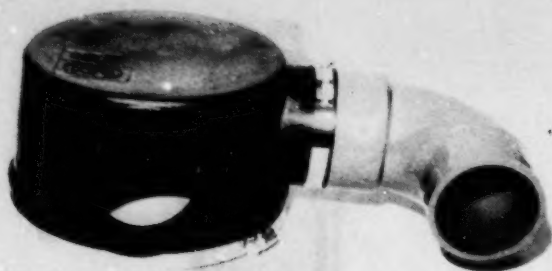


FIGURE 15.

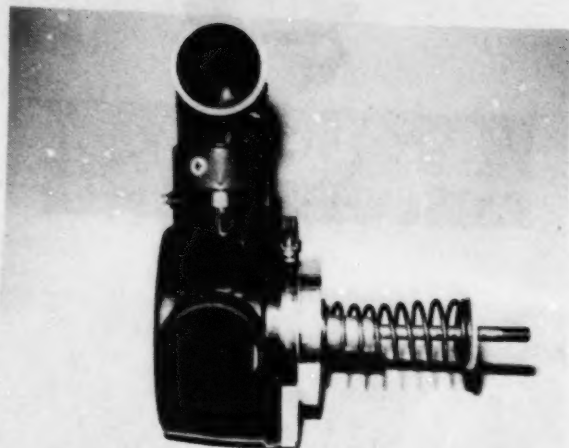


FIGURE 16.

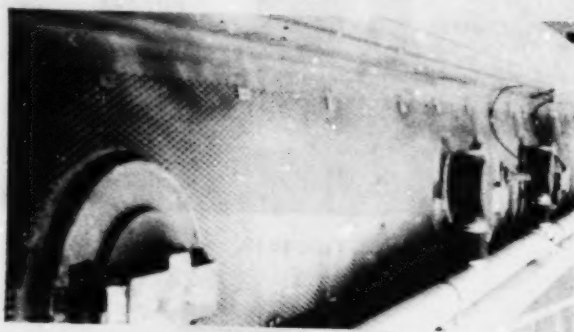


FIGURE 17.

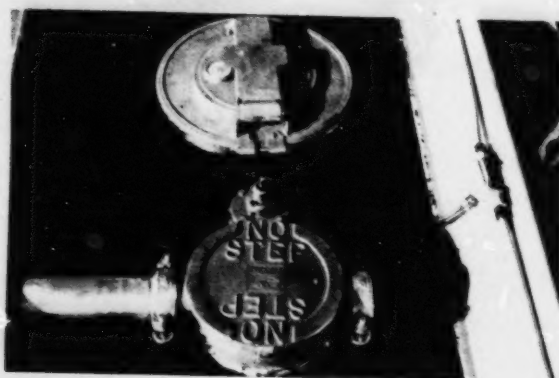


FIGURE 18.

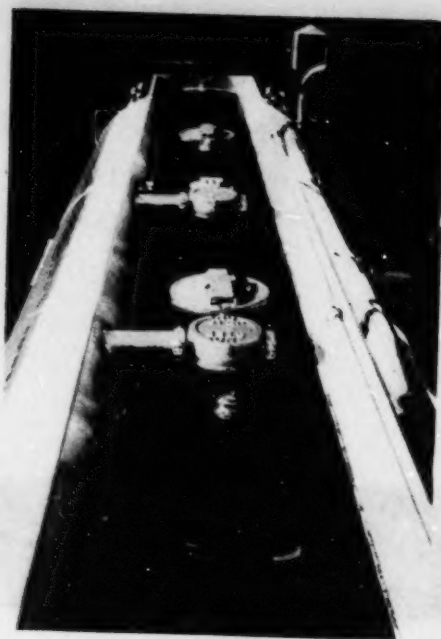


FIGURE 19.

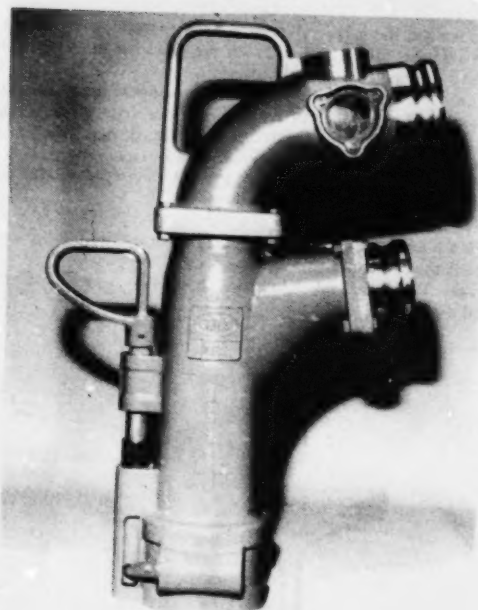


FIGURE 20.



FIGURE 21.



FIGURE 22.



FIGURE 25.

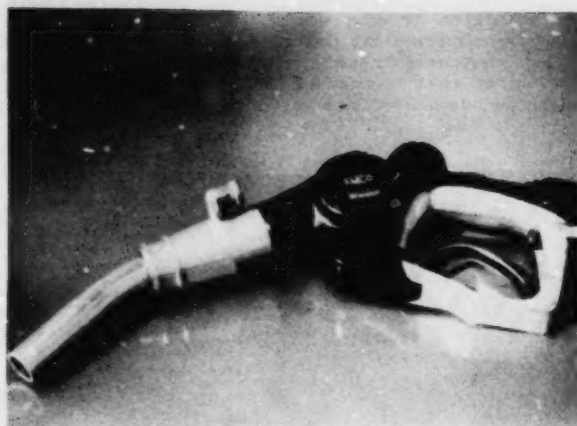


FIGURE 23.

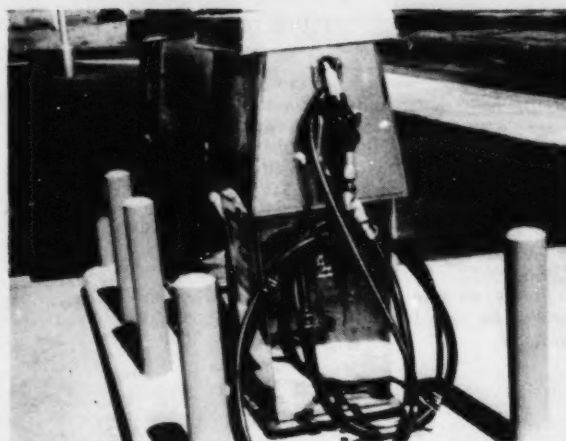


FIGURE 26.

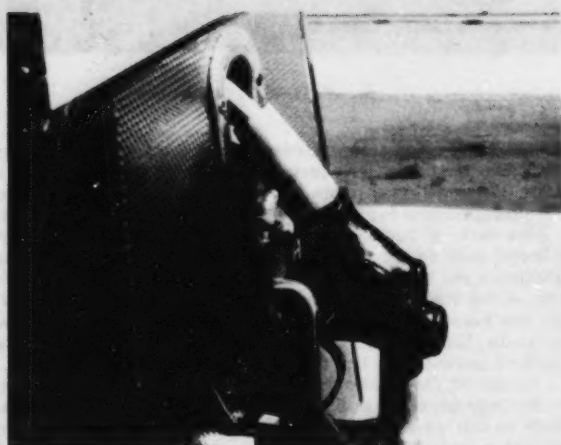


FIGURE 24

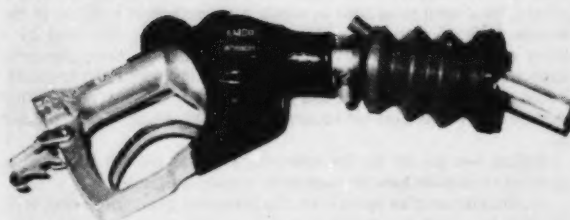


FIGURE 27.

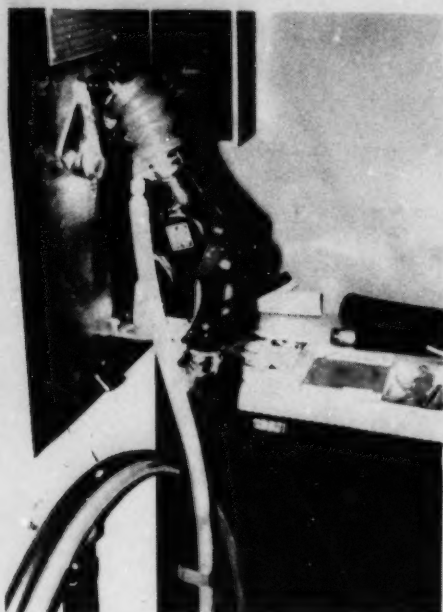


FIGURE 28.

Now, the equipment shown in Figure Twenty is the reason for our trip here, as far as I am concerned. It is our coaxial vapor recovery system for underground service station tanks.

We can install the tube and the adaptor you see in Figures Twenty-One and Twenty-Two. In fifteen minutes we can convert each tank (at a cost of less than \$100.00) to service station vapor recovery. We are achieving recovery rates in excess of 90%, and we are effectively maintaining the flow. This piece of equipment is by far the least expensive available for recovery of vapors at the service station.

Finally, we have a series of Figures showing our vapor recovery nozzles. We have two different types available. Thank you very much.

II. W. B. Hansel

Good Morning. I would like to talk with you this morning about the operation of the automatic nozzle, with regard to vapor recovery. We heard several times yesterday about the need for improvements in the nozzle. What we did not hear yesterday was how often a malfunction of the nozzle occurs due to its operation in conjunction with vapor recovery.

In our EF-14 Task Force surveys, the percentage of what was termed "premature shut-offs" made up almost 30% of the total number of operations. This became a matter of concern. In further research, however, we found that perhaps some of the shut-offs were not necessarily, premature. Some shut-offs occurred later than others. We found situations in which pressure would build up in the vehicle tank. A very high pressure would then be followed by a burst of liquid coming out of the tank filler neck. Sometimes the back surge would go into the vapor return line, but most times the liquid would break the seal and spill on the driveway. We think that we know how this shut-off occurs and why. We think we can correct it.

Before we go on to the solution, I would like to take just a moment to explain how an automatic nozzle operates.

Automatic nozzles operate on the following principle. There is in the nozzle a power generator which creates a low pressure. The pressure is then vented to the air inlet in the filler neck. When the nozzle liquid is flowing, air is pulled into the system and vented to a diaphragm section. The air is then pulled back into the venturi.

With normal operation, the pressure in the diaphragm section chamber is a little less than atmospheric. When liquid comes up the fill pipe and covers over the entrance, the low pressure generated by

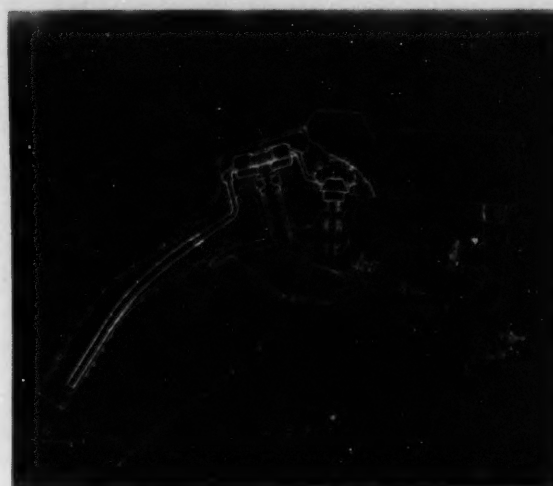


FIGURE 1.

the venturi, on the other side of the diaphragm, is vented to atmospheric pressure and that atmospheric pressure pushes the diaphragm, releasing the quick-release mechanism that is attached to the fulcrum which operates the handle for the main valve. The nozzle shuts down when this inlet is closed.



FIGURE 2.

The same nozzle, when combined with vapor recovery, produces problems. There may be a pressure build-up in the tank due to a restriction in the vapor return line with a condensation of liquid, or due perhaps simply to an odd configuration of fill pipe. The result is a blow-back of liquid. Pressure builds up in the system and is reflected back to the top of the diaphragm, pushing down on the diaphragm and keeping the pressure in the diaphragm section above that of the atmosphere. If you do then get this liquid blow-back, pressure has already built up and the nozzle will not shut down. The nozzle has become a sort of self-destruct mechanism. The result is a spillback and over-flow that I described.

To correct the problem, we have taken a vapor balance line back to the underside of the diaphragm. We put a seal around the fulcrum shaft, so that we could maintain some pressure in there. Now, when we get a pressure build up, the nozzle functions as it should function, with a very small Delta P across the diaphragm. The tank pressure itself does the pushing rather than atmospheric pressure.



FIGURE 3.

We feel that the automatic nozzle, as it is today, is an atmospheric nozzle. If it is to be used in a program of vapor recovery, that nozzle must operate with the tank pressure, rather than atmospheric pressure, as a reference. I thank you.

III. R. J. McCrory

Mr. Chairman, in Detroit during May of 1972, Gilbarco reported on the detailed results of over three years of research on vapor recovery nozzles. We published these results in a report which has been widely distributed throughout the industry. This report signified the end of several years of frustrating and costly work. We encountered technical problems in the inaccessibility of fill pipes on automobiles (which, incidentally, have gotten worse instead of better) and in the fading away of commercial justification. In other words, that time period just was not right.

We learned a lot in those days, however, and now in December 1973 I can tell you that Gilbarco is back in the ball game. Our objective is to come up with a vapor recovery system which will meet the so-called Stage 2 requirements, from the vehicle tank back, within the service station environment. This is a decision made from evidence given by a number of our customers that they truly need such a system.

Gilbarco has a system, we feel, that will meet the transaction requirements for selling gasoline, as well as the economic requirements. Our system includes everything from the nozzle interface with the vehicle back to the point at the service station where the vapor is recovered.

Our specifications for the Gilbarco system are clear. First, there can be no vapor mixtures in the explosive range in the system. Second, there can be no ignition source that might ignite any explosive vapors which do exist. Third, there can be no trap that a fuel kickback could be stored in. Fourth, there must be a fail-safe provision against any hydraulic shocking from the dispenser to the vehicle fuel tank.

In terms of transaction requirements, our specifications for the system will be in accord with weights and measures regulations for correct customer delivery; the system will have a proper nozzle hang-up and reset interlock. The system will be simple to use and therefore suitable for self-service.

In terms of economics, the system obviously must have reasonable equipment and installation costs, along with low operating cost. We view the system as being modular, such that the size and performance rating will be in accordance with the requirements of the particular site. The system must involve, in our view, single-sourcing on the part of the oil companies. The supplier must be responsible, having his equipment carefully backed up by service warranty and spare parts availability.

Gilbarco will introduce this system when it can meet the following criteria. One is that the system be capable of UL listings. I hasten to add that we would not favor any suggestions for a relaxation of UL monitoring of safety in gasoline dispensing equipment. We will also have a weights and measures review at the national level. Our system will be thoroughly developed and tested. We will allow for retrofitting of existing stations with existing pumps.

This is our idea of a realistic system, gentlemen. The development of such a system is consistent with our responsibility to our customers and to the public and remains Gilbarco's basis for doing business in vapor recovery. Thank you.

IV. G. E. Moore

OPW is vitally interested in vehicle refueling problems at the automobile interface. Many of you are familiar with the OPW 7VR nozzle. This nozzle has served as a test vehicle for OPW and for a number of oil companies in determining what is required for vehicle refueling. OPW has furnished several of these nozzles to various test sites around the country, especially in California. All in all, we think the nozzle has proven extremely valuable and has given us, as a nozzle manufacturer, information which could not have been obtained in any way other than production.

The 7VR nozzle has helped define problems related to vehicle refueling emissions. First, there was the problem of making a seal in the various fill-pipe configurations. We found that most complications lie in the fill pipe area itself, including the location and orientation of the fill pipe, as well as the sheet metal surrounding it. This problem is compounded on some vehicles by the tolerances in the location of the fill tank.

After making a seal, the nozzle should remain sealed. In making any seal which involves filling of the car (since the pumping unit is capable of producing up to 50 psi, with an average of 25 psi, we felt we should provide a maximum pressure shut-off means. Maximum pressure was determined in several ways. We concluded that pressure should be in the area of 10 to 18 inches of water. While we were not certain exactly what the Underwriters requirements were for vapor recovery nozzles, we felt we could meet most of the existing requirements. Reliability should approach that of existing service station nozzles.

We felt initially that the vapor return passageway, which was under the nozzle at the time, would be satisfactory at a 7/16-inch diameter. Later tests, however, proved that the vapor return line must be larger, so as to keep the pressure drop in the vapor return line lower. Handling was of concern as well. Another consideration along these lines was the use of a valve in the nozzle line to prevent back-flow of vapors from either an adjacent nozzle or from the underground tank.

As a result of this testing, using the 7VR, we have designed the OPW 7V nozzle. Our nozzle looks similar to others, but actually is quite a bit different. We feel the OPW 7V provides solutions to most of the problems we found during our evaluation testing.

The 7V nozzle has a swivel seal on the front to allow a fit with the majority of fill-pipe configurations. We would be the first, however, to add that no one can expect to attain a complete seal on 100% of those vehicles on the road today. The swivel seal, however, provides more than just the seal in the fill pipe. We have built in a valve at the seal itself so that when inserted into the fill pipe the valve opens and vapors are allowed to flow back, or can be drawn back through the vapor return passageway. When it is removed from the fill pipe, there is immediate re-sealing against the brass ring to prevent back-flow of the vapors. The brass ring also retains the nozzle in the fuel pipe.

In tests conducted last month by several oil companies, we maintained a seal in approximately 95% of the vehicles refueled. The 7V has a full 3/4-inch vapor return passageway, keeping the pressure drop in the range of 1/10 of an inch of water in the flow ranges we are talking about. The vapor return passageway not only is large, but also is part of the nozzle itself. We are using a bellows arrangement which has proven successful.

While we at OPW do not have sufficient test data—nor are we equipped for testing to determine what is actually feasible on vacuum return systems—we have designed the nozzle so that the seal will be maintained. We would, however, like to add one word of

caution concerning allowing excess air into the system. Any excess air presents a very real danger of an explosive mixture.

I would like to close with recommendations for directions in which I think future vehicle refueling interface research should proceed. The nozzle can accomplish only so much, depending generally upon the fill pipe and other considerations in the car. While it will not be formally introduced at this time, the 7V nozzle should be considered during any future vehicle design and styling. The 7V nozzle is not commercially available at this time. Prior to manufacturing and tooling up, a great deal more testing will have to be conducted. Thank you.

V. A. W. Percy

So far, we have heard about vapor emissions problems and solutions stated in broad terms by the petroleum industry, the automotive industry, the research contractors, various levels of government, and now—in more specific applications—by the equipment suppliers. A key link between the need for control and the application of equipment is the service station dealer and his employees.

Today, I would like to speak on behalf of a Union dealer operating a service station equipped with a vapor recovery system. This dealer has experienced the start-up and development of the vapor control equipment. His station was not the first to have this equipment installed; indeed, he was at least the third in his general area. So, presumably he is not facing all of the development problems associated with new systems.

We must remember that he is an independent businessman. He buys products from a supplier company and sells them for a profit. He hires people to sell the products for him. How has his business been affected by vapor recovery equipment?

Nothing can be rated on the positive side for this dealer.

Any value associated with the vapor control equipment is marginal and does not make a significant contribution to his operation. He has had no rush of new customers wanting to buy gasoline from a station equipped with vapor recovery hardware. Indeed, some customers may have been driven away during periods when tests were being conducted and the delivery transport was present for an abnormally long period. To date, he has experienced a problem of general unreliability related to the nozzle, the installation design, and the equipment itself.

With regard to moving vapors, if a tight connection has been made on the fuel pipe during filling a car and there is no place for the vapors to go, pressure builds up in the customer's gas tank. This pressure can result in a sudden gush of gasoline from the customer's tank when the nozzle is removed. A wet, irate service station employee, a disgruntled customer with a soiled car, and spilled product more than offset any vapor control contributions to atmospheric quality.

An unsafe condition exists as well. This spill, remember, is not related to overfill of the car. If the vapor return boot on the nozzle slips, is cut open, or removed, this pressure cannot build up and deliveries can be made in a normal manner. Such a disconnection represents a simple solution to the dealer's problem, but is no improvement in the emission problem.

Meanwhile, subsequent installation of other vapor control equipment in other locations is being proposed for Union Oil by contractors. These installations contain the same problems that have occurred at this station.

Underground vapor piping that goes from the dispenser to the process unit has no provision for draining condensate or liquid splashback from the trap. Consequently the piping provides a future blockage to vapor flow. Vapor lines are looped at the dispenser, trap liquid gasoline, and must be carefully stretched out to drain. We receive equipment components that have not been completely tested or even operated very long in the real service station environment.

We are all learning to walk in an infant industry. If we try to run too soon, we will endanger the million people who work in service stations and the hundreds of millions who visit them. We need equipment that is reliable and safe. Finally, we need a reasonable time in which to develop such equipment. Thank you.

VI. H. J. Silver

In 1972, Texaco installed vapor control piping at nine stations in California to evaluate, under operating conditions, a variety of valves, connectors, and vapor balancing or displacement systems. On the basis of our test results, we have selected a piping arrangement which has vent lines from all of the underground tanks joining a single vent line to atmosphere. On this single line, we have an OPW 1631 or VRL valve that is used to connect the tank vents to a vapor hose going back to the truck. When this hose is connected, the line to atmosphere is automatically shut off. We found that with this displacement system, we did not aggravate normal operating conditions. Everything was as safe as before the installation.

We also found that we had an average of 96% control effectiveness using a 2-inch vapor hose with a 2-inch valve. When we went to a 3-inch valve, still keeping the 2-inch hose, our effectiveness improved to 99%. Using this system and other proven, commercially available equipment at the terminal and at the station, we can control 78% of our total hydrocarbon losses in a typical product distribution system without any auto refueling control.

If we place carbon canisters or any other type of system on this vent line at the station, we will improve the degree of control by less than 1%. Thus, control on the vent apparently contributes insignificantly to overall reduction of vapor emissions. When we have acceptable and effective tight fill nozzles, that percentage increases to 92% of emissions in the overall distribution system. This control will be attained without any device on the service station vent line or any vacuum assist.

The results of our in-house nozzle development work and vacuum assist tests were very unsatisfactory. To date, only one company has provided us with experimental nozzles to test in the field and in the lab. With the first design, we had five major problems: insertion, automatic operation, splashback, durability, and compatibility with the auto fill necks. Last month we began testing an improved design, and the initial results are very encouraging. We believe, however, that tight fill nozzle development has not progressed sufficiently to provide for capture of all displaced vapors during vehicle refueling.

In our laboratory tests on vacuum assist, we experienced hydrocarbon concentrations in the vapor line in the explosive range of about 5%. We do not know of any fully engineered vacuum assist systems. But if we did, we couldn't recommend such systems because of the possibility of producing an explosive mixture. These systems, in our opinion, are interim measures.

In summary, we have found that a high degree of control can be achieved without capture of vapors during vehicle fueling and with no control on the service station vent line. More control in these areas can be obtained when a safe, proven, tight-fill nozzle is commercially available. The use of vacuum assist is only an interim measure, creating many problems and requiring complex, unproven equipment at the station.

VII. R. L. Cisco

Good morning. We would like to present the Parker-Hannifin single point fuel delivery vapor collection system for use when the product is transferred from tank truck to underground service station tanks. This system is sometimes known as a coaxial or concentric approach. The major advantages of this coaxial or single point system are many.

First, this system eliminates any interlock problems concerning whether or not the driver would hook up the vent line. Our system is automatically hooked up. Second, our approach provides no flow restriction for delivery of product. Under actual service station tests at one of the API test stations, we actually showed equal or slightly better drop rates than those of the standard configuration drop presently used. We have achieved these results by careful engineering of every item in the system. Third, we feel our system has the advantage of ease and speed in hook-up. Studies have shown that a single connection hood-up will prevent loss of time in service station deliveries. Finally, the adaptor portion of the system can be equipped with or without a check valve on the vapor side, as required by a regulatory agency.

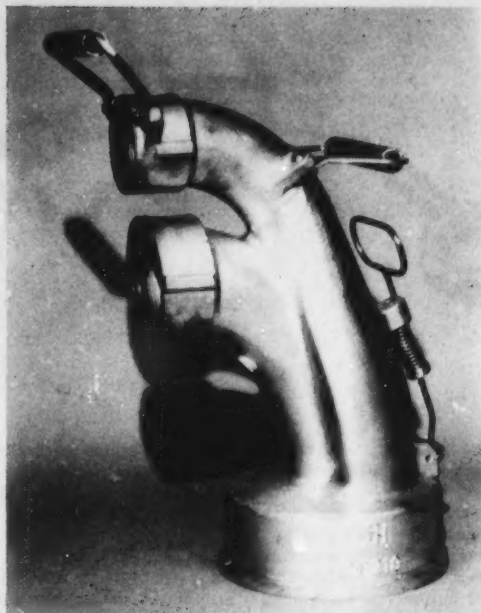


FIGURE 1.

I would now like to show you some slides of the equipment we have in production at the moment.

Figure One is the F219 Coupler, which utilizes a 3-inch vapor hose and a 4-inch fuel connection. Please note that the vapor hose is the top connection.

It has the F434 Adaptor utilized in the service station. An integral part of the system is the drop tube, which is custom made for each specific station to prevent flow loss of gasoline.

Figure Two shows schematically the items connected. Ease of hookup is provided by a single push-on, pull-off type of connection.

In summary, this approach, although not applicable to every station in the United States, will have no restricted product flow and will meet the regulatory requirements for vapor recovery. Thank you.

VIII. R. C. Slawinski

Mr. Chairman, ladies, and gentlemen, over the years, manufacturers in our industry have been able to supply equipment



FIGURE 1.

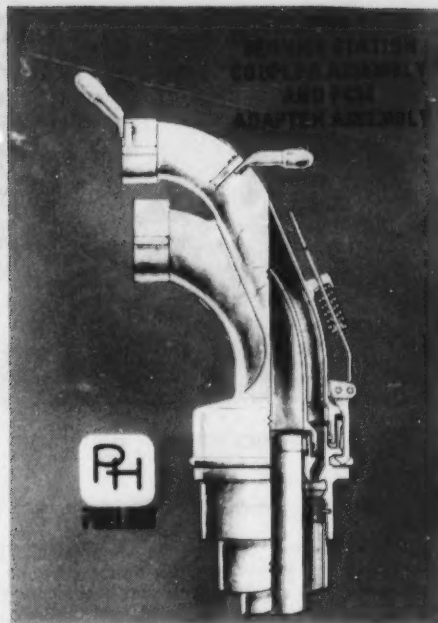


FIGURE 2.

necessary to get the job done. A good case in point involved the cooperation between suppliers and industry to design a 100% interchangeability into a dry-break adaptor system, using the guidelines in API specification RP1004. (See Figure 1.) This morning, I would like to single out an additional item that needs spelling out in greater detail. I am speaking of the specifications covering vapor recovery adaptor standards.

Yesterday, we learned from the various air pollution control people that a 3-inch connection is necessary. This morning, some of my worthy competitors also advocated a 3-inch connection. Most of us agree that the equivalent area of a 3-inch pipe size is sufficient to handle present day vapor recovery. Along with pipe size, however, we now face the problem of whether or not a dry-break connection is required. In some states, the decision has been made for us. A closed end system at the loading rack, the service station, and tank truck is now a requirement. Under these conditions, to maintain the effective area of 3-inch pipe, or approximately 7 square inches, we would recommend that the industry adopt as standard a 4-inch size in the cam and groove configuration. This size would allow manufacturers to meet the minimum effective area required, should a dry-break feature become a national standard. I believe that the API committee handling this matter has a ballot out to member companies concerned with a similar recommendation. I sincerely hope that other agencies having an influence on this standard will also speak out.

The features incorporated in our dry-break system allow for an inexpensive unit to be used where an open system is permissible. The system also allows installation of a closed end system with a manually operated butterfly valve which could not be coupled until the connection was actually made and opened. One cannot expect to maintain the requirement of 3-inch pipe size and still add the necessary valving. Please give this your consideration in designing future systems. Thank you very much.

IX. E. Copony

We have developed two nozzles which have application to a vapor recovery system. These nozzles are presented now as equipment that might be of interest to the participants in this seminar.

Our first nozzle was developed to satisfy the requirement for a self-service nozzle. It provides safety features. It can be opened only when properly inserted in an automobile fill pipe. At the same time,

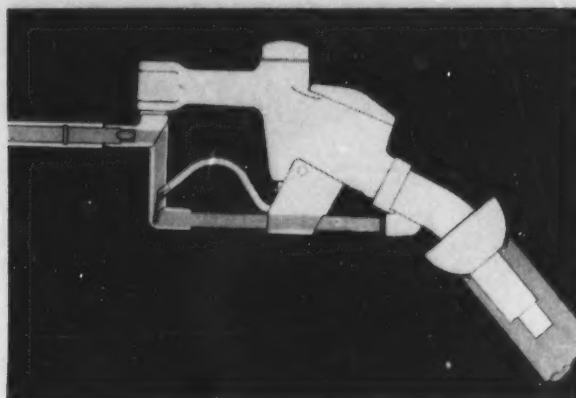


FIGURE 1.

the nozzle provides for removal of fueling vapors to a remote location.

Our original intent was to carry the vapors away from the dispensing point so that a customer with a cigarette in his mouth would be not exposed to danger. The vapors at the remote location could then be passed into a vapor recovery system. Each gasoline pump or dispenser would then be equipped with a vacuum pump to carry the vapors from the vacuum hose connection on the butt end of a nozzle via the hose back to the vacuum pump, which would discharge wherever desired. The individual vacuum pump could then be eliminated and a central vacuum system utilized. Possibly a displacement type method for removing the vapors could be applied.

Figure One shows the nozzle fully inserted in the fill pipe. When in this position, the automatic nozzle can be opened. The hemispherical nosepiece seals on the faying surface of the fill pipe, providing a partial seal to the annular vacuum passage on the nozzle spout and completing the vapor path from the fill pipe to the vacuum system. When the nozzle is removed from, or not fully inserted in the car fill pipe, the hemispherical nosepiece (which is spring loaded) closes a valve in the spoiler tube, preventing operation spring loaded) closes a valve in the spoiler tube, preventing operation of the nozzle. (See Figure 2.) This nozzle requires that the attendant or customer hold the nozzle in the filling position during delivery.

Figure Three demonstrates another nozzle development. This nozzle is designed to be operable only when properly inserted in the fill pipe, as demonstrated in the picture. As originally intended, the faying surface between the bell shaped housing and the fill pipe does not form a tight seal. The nozzle could, however, include a vapor passage for use in the tight-fill and vacuum vapor recovery systems. Again, this nozzle was intended for self-service and requires that the customer or the attendant hold the nozzle in the proper filling position during operation. Removal of the nozzle from the fill pipe permits the bell-shaped housing to move toward the end of the nozzle, shutting the nozzle off. The nozzle cannot be opened again until properly inserted into the fill pipe.

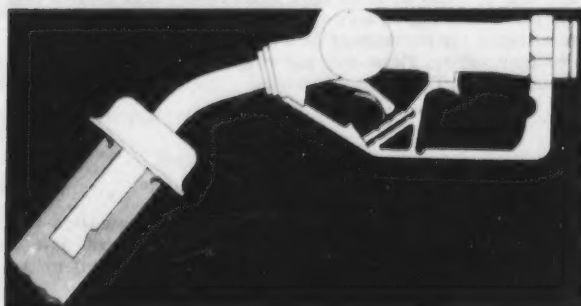


FIGURE 3.

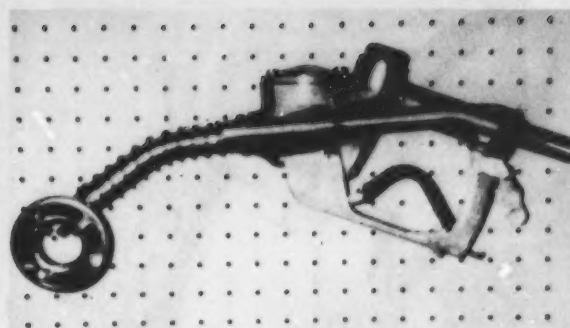


FIGURE 2.

The development of vapor recovery nozzles and other elements required for complete vapor recovery systems is being carried on by Dresser Industries, Inc. on a high priority basis. Our opinion, however, is that the variety of fill pipes, fill-pipe sizes, configurations, leaded and unleaded nozzles, and cosmetic treatments of the areas around the fill pipe make highly desirable a standard fill pipe configuration. If a standard design were adopted by the automobile companies, a satisfactory means of interfacing the vapor recovery nozzle and the car filler pipe could be attained by our industries. Such a solution would apply not only in the United States, but also in other countries where the need for vapor recovery systems will eventually emerge. Thank you.

X. G. G. Sutcliffe

Husky has been developing vacuum assist nozzles for a couple of systems. We have taken the basic design nozzles in use today and have tried to build a low-cost, simple, yet effective kit to collect gasoline vapors. The kit we have developed is not proposed as a final answer, but as something to build on. The kit can be equipped with devices such as extensions on the flame arrestor, pressure release valves, or vapor return line valves as required by the various systems the kit is attached to.

The kits on this nozzle shown in Figure One consists of three parts. First, we have a flame arrestor located at the vapor collection point. This arrestor is held in place by the collection boot. Second, we see that the vapor return line is attached to the nozzle by clamps.

Third is the plastic collection boot incorporated into the scuff guard. We have gotten a one- to two-year life out of this type of guard and collection boot at our test stations.

Figures Two and Three are two views of the completed nozzle kit, showing the flame arrestor, vapor return line, and collection guard. The nozzle is not designed to make a tight seal at the fill

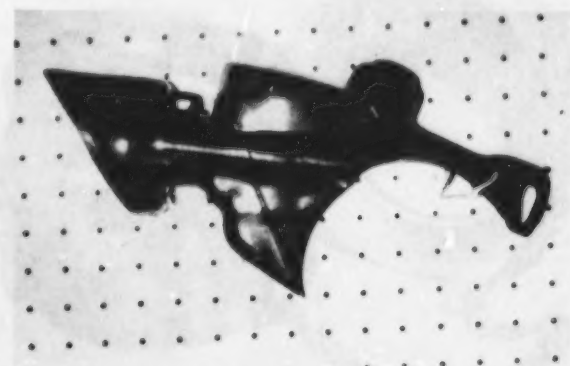


FIGURE 1.



FIGURE 2.



FIGURE 3.

pipe. Our design fits in the general proximity of the fill pipe to catch the vapors as they come out. Our nozzle also draws in some of the surrounding air to insure that no vapors escape. This way there is no chance of over-pressurizing the tank in case the nozzle should fail to shut off. Finally, negative pressure is not applied to the tank itself.

This nozzle has been tested on various systems, with promising results. The model is excellent for retro-fit, since it does not need a tight seal on fill pipes to be effective. Our nozzle fits in most existing pump boots, is simple, and is easily installed at point of manufacture or during rebuilding of existing nozzles. Thank you.

INTRODUCTION BY THE SESSION CHAIRMAN

MR. BRATTAIN: Gentlemen, we have come to the second part of this morning's program. I now am going to introduce our next series of speakers. We have Mr. J. L. Gockel of Clean Air Research, Mr. Y. C. Lee of Envirionics, Mr. J. Perry of Vaporex, Mr. Taylor of Intermark Industries, Mr. Fusco of Calgon, and Mr. Datis of Process Products incorporated. After these gentlemen have made their presentations, we will have a discussion period.

EQUIPMENT PANEL I. J. L. Gockle*

I would like to preface my description of our equipment by going back to yesterday's session for a moment. The kind of control we are talking about is a stationary source control which can be regulated reasonably well by the specific enforcement region.

Selection by the regulatory agencies of a particular type of equipment as necessary will depend largely upon what degree of hydrocarbon control is required. Selection will also depend upon whether the users, the oil companies, or the public would have to pay for a "displacement only" system (such as Mike Leiferman described this morning) or whether there would be an extension control by calling for a secondary recovery.

Last night, I made a few calculations of cost-effectiveness that may be useful for comparison. Now I will describe—just for a moment—the two basic system approaches. First is the "displacement only" system. The second is a secondary approach, aimed at recovering vapors that would not be recovered in the displacement procedures.

Our calculations and analysis of the data, however, differ from Mike's. We think that the excess vapors and diaphragm losses, along with other external vent losses, will account for about 25% of the total. Displacement would be effective only on that basis, and that is the basis on which I made these cost-effectiveness calculations. Secondary recovery units should be able to recover most of any remainder. In these calculations, I found that the primary vapor recovery system is extremely cost-effective. The system is 10 to 20 times more effective than any other kind of strategy. If there were any kind of hydrocarbon problem in a region, I am sure that this system would be a minimum requirement.

The secondary vapor recovery, based on the percentages I mentioned, turns out to be about five times less cost-effective than the primary system. The result is very bad on the surface. Yet, I also calculated the savings associated with a 1974 car, as compared to a non-controlled car. I found that secondary vapor recovery for the former is three times less cost-effective than the latter.

Further, we have a retrofit program being implemented in California, to be stepped up in January. Secondary vapor recovery is 1½ times more cost-effective than is that program. Secondary recovery systems could be implemented, for example, in San Diego. People there might be willing to pay a quarter of a cent more for gas per gallon to be able to park down town again.

Our system is based upon the adsorption of hydrocarbons in activated carbon. There are two canisters in the system. The system includes on-site regeneration, so that when the hydrocarbons are being adsorbed in one canister, the other canister is being regenerated by the vacuum pump. The vapors are then taken from the vacuum pump (at this point they are completely saturated hydrocarbon) and fed into a condensing unit, after which they are returned to the underground storage tank. All piping and wiring are explosion proof. (See Figure One.)

Figure Two shows a different view of the unit. Both canisters may be seen in the back. At the bottom is a vacuum assist system which is used to pull the vapors from inside the tank. A tight seal nozzle can be very, very difficult to operate successfully, and the vacuum assist may be necessary. A secondary recovery unit is automatically necessary with the vacuum assist.

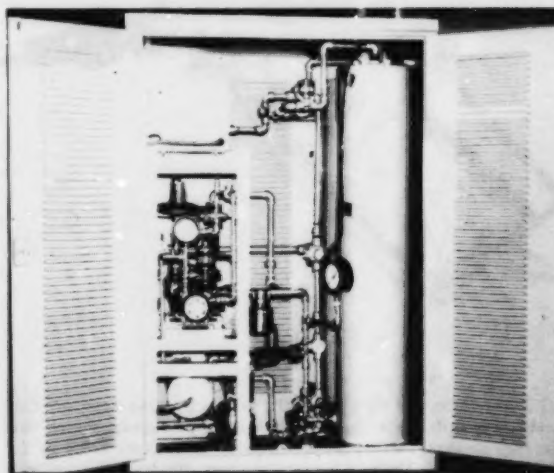


FIGURE 1.

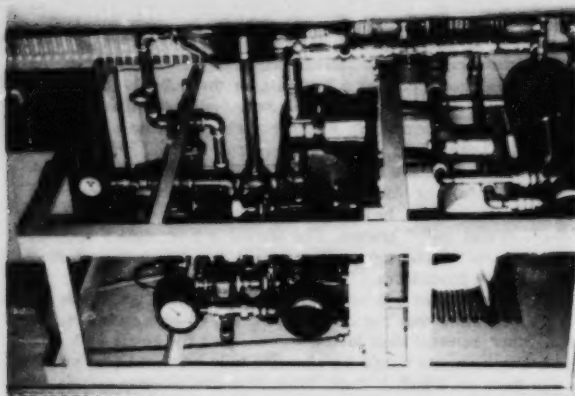


FIGURE 2.

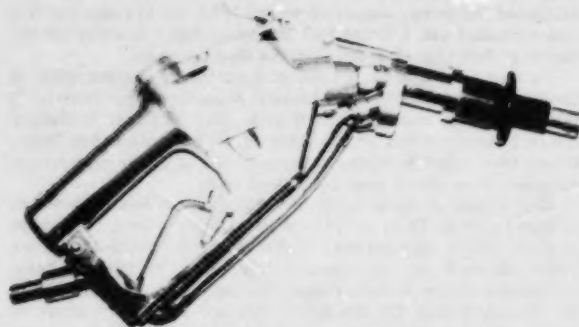


FIGURE 3.

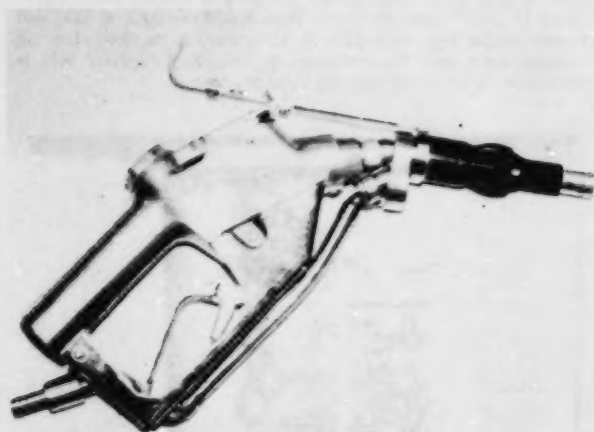


FIGURE 4.

Figures three and Four show the nozzle we have designed. Our nozzle is a little different from the ones previously shown this morning, in that the vapors are brought in through holes in the expanded annulus. The unit is made of a very durable polyurethane rubber. In use with a vacuum assist type system, our nozzle has the advantage of picking up the vapors while actually down inside the

fill pipe. We have a pressure relief valve, which is set at half a pound pressure, in case the nozzle should fail to shut off. The gas tank on the vehicle wouldn't be injured then.

Down in the lower corner is a small object known as a tilting check valve. When the nozzle is holstered in the pump, the ball falls in its seat and prevents any excess air from coming into the system. When the nozzle is tilted, being used, the ball falls out of its seat and then vacuum may be drawn onto the tank.

We think that this system has merit. Some advantages are that it requires a relatively low amount of power; it has no pressure in the underground storage tanks; and it recovers vapors rather than incinerating them. In an energy crisis, this function could be relatively important. Our device should be well over 95 percent effective. It is easily adaptable to any size service station simply by changing the length of time between regeneration cycles. Our unit is relatively low-cost.

I would like to conclude by saying that we are pretty enthusiastic about the principles involved in onsite regeneration. We are now looking at the possibility of using our system in larger units for bulk terminals. Thank you.

H. Y. C. Lee

The Enviro-nics system is basically a displacement system coupled with a carbon canister to capture and process emissions from underground storage tanks during dropping as well as those emissions from the automobile filling. The basic principle involved is use of a carbon canister to store hydrocarbons and then process them at a mode compatible with a given station's operating conditions. If a station dealer is open during the day, he can process this gasoline vapor at night. If the station is open 24 hours, our system can be completely automated so that it is compatible with overall operating schedule.

At the present time, we have three models being manufactured for delivery to San Diego County stations. The first model takes care of through-put up to about 10,000 gallons a month. The second model is capable of taking care of through-put up to 60,000 gallons a month. The third unit is capable of 120,000 gallons through-put per month. Each unit has the number of hoses associated with that particular amount of through-put.

The system consists basically of two carbon canisters and a process unit. One canister is used solely for the dropping. The carbon canister presently designed is capable of processing or storing 30% of the maximum drop (about 8,500 gallons). The second canister is primarily used for the dispensing operation. We have obtained a permit for the middle size model to operate within San Diego County. This unit, incidentally, has eight hoses. We are currently manufacturing the larger one and the smaller one.

There are three unique characteristics to our system. We think the use of a sealed nozzle represents a very difficult problem to resolve. Accordingly, we designed our system in such a manner that no nozzle-seal is required. Our nozzle will take in adequate amounts of air to mix with the gasoline vapor that we then pump through the carbon canister and send to a catalytic converter for processing. To date, our process is approximately 95% efficient.

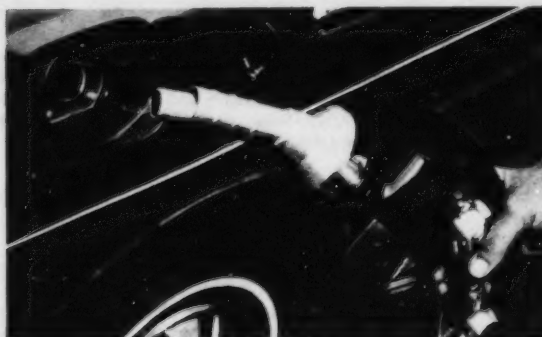


FIGURE 1.

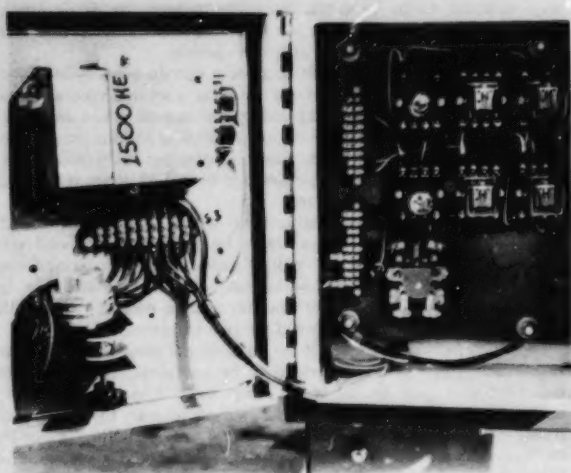


FIGURE 2.

The second unique feature of our system is the modular design which provides volume growth without great expense. We can increase the carbon canister size, should that become necessary, or we can modularly put two canisters together. Third, I think our system is relatively simple, reliable, and cost-effective.

I want to show you the experimentation we have done with the nozzles. We have been modifying both the standard OPW and Emco-Wheaton nozzle. We have experimented with various configurations of nozzles. Basically, the nozzle is a concentric tube which fits on the outside of the standard nozzle and with a conical end. (See Figure One.) This is a modified OPW nozzle. This is the section that we add on to the standard nozzle, and, with the conical section, we can fit almost any filler neck configuration.

Figure Two shows the control box.

Figure Three is our process unit and canister.
Thank you very much.

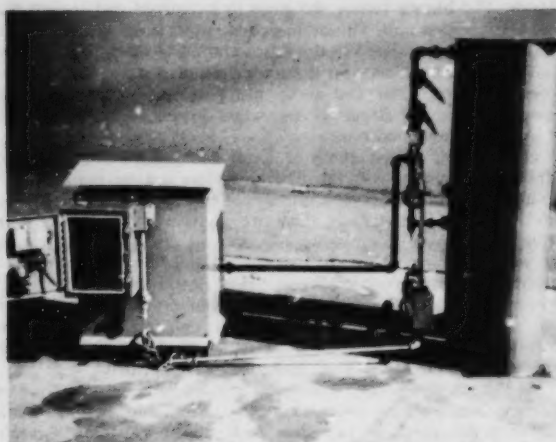


FIGURE 3.

III. John Perry*

I would like to describe to you a system designed for both bulk plants and gasoline service stations. Bulk plants we define as a kind of wholesale service station where truck deliveries are taken and dispatched. The system we have developed is essentially identical for both station and plant. I will describe in detail what the components are and what they do, shown in Figure One.

Our system is a balance system with an add-on, as Mike Leiferman explained. The add-on is straight refrigeration and a method of circulating the vapors through the system. During a dump of liquid product into the underground storage tanks, vapors return in some proportion to what was delivered, never any less than what was delivered. The excess vapors cause the pressure in the system to increase, which, on a pressure signal, starts the circulation

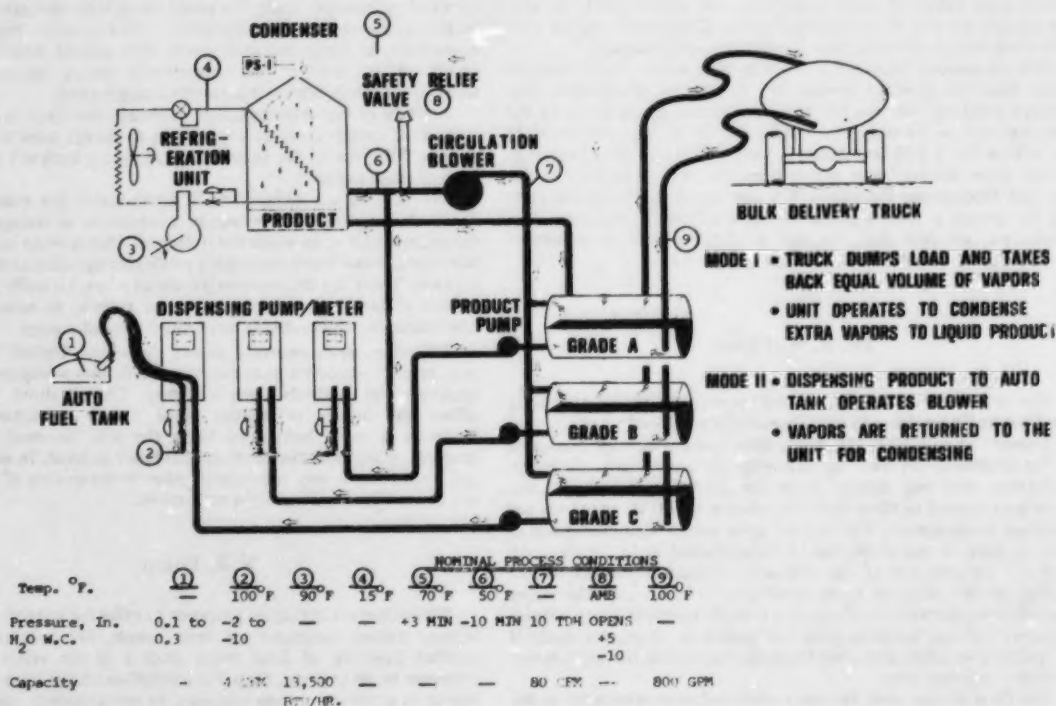


FIGURE 1: Vaportrol Flow Schematic.

blower. The blower causes the gases to go around and around the cold refrigeration coil. This action condenses a small amount of the product being circulated in the vapor and cools the vapors as they are being delivered back to the underground storage tank. Over a period of time, after the dump has been completed, the unit continues to run, shutting off only when this pressure is back down to an equilibrium condition.

On an 8,000-gallon dump at about 850 gallons a minute, the refrigeration system and the blower system are on for an hour, perhaps an hour and fifteen minutes. There are many variables in this average time, but more than two hours would be unlikely. A fifteen-minute run occurs sometimes. On the average, this unit runs for an hour during a dump. Essentially, then, we have a balance system with some assistance from the refrigeration and circulation blower. Our device results in 100% containment of the vapors that were generated from a difference in vapor pressure, a difference in temperature, or a difference from some other source. There are three or four sources that can cause excess vapor growth.

At the island, we have a different problem, and we have tried to separate this problem in a certain way. From the section of the blower to the island, we provide a small vacuum-assist but we don't allow this assist to go to the automobile tank. We regulate, with a very large diaphragm pressure regulator, the pressure in the vapor return line to the auto tank. We use a slight positive pressure so that if there are leaks or inefficiencies in capturing this vapor at the tank, the leaks are out and not in. We thereby guarantee that this vapor space in the auto tank doesn't go into the explosive range. The vapor line down to the anti-air valve is not in the explosive range because it includes the same composition that you would have in the vehicle tank.

From this point on, if the lines are tight, there is no hazardous mixture being handled into the system. This safety condition is gained by limiting our interface connection to a positive pressure connection, so that displacement of vapors into the system is always at a very slight positive pressure (plus 0.3 of an inch of water). All leaks are out. We feel that this is a vital consideration in the system design, because the hazards of handling lean mixtures are well known in the industry. To give you some idea of the economies involved, the operation of the system, as I mentioned, is an hour to an hour and a half average during a dump. This refrigeration unit is about 1½ horsepower. You therefore have 1½ horsepower of hours per 8,500 gallons of delivery. If it is a 200,000 gallon a month station with deliveries every other day, the figure is only ¼ of a horsepower per day. If delivery is 30,000 gallons per week, our unit may represent a lower cost than the lights in some stations.

The circulation blower is a ¾-horsepower motor that comes on every time the product pumps are turned on. Each time you dispense product, you can put this small minus pressure not in the tank, but out to the island by turning on this circulation blower. If the unit is for a 200,000 gallon a month station, this circulation blower is on several hours per day, or whatever proportion of the day that through-put calculates. The cost would still be pennies per day to operate a ¾-horsepower motor. So from an operation cost standpoint, we feel that our unit provides a kind of minimum operative level. Thank you.

IV. R. W. Taylor

The system I want to talk to you about, although referred to as the Atlantic Engineering System, is manufactured by Intermark.

During the past 10 to 15 years, there has been growing concern in the United States over our changing life style, particularly the realization that our natural push for growth and progress has sometimes tended to blind us to the adverse effects this progress has upon our environment. Whether we agree with environmentalists in total, in part, or not at all, they have awakened us to the absolute need for preservation of the physical conditions essential to our quality of life. One of these conditions is clean air. The move toward vapor recovery at all gasoline transfer points is a very natural outgrowth of our concern about air pollution. As greater controls are realized in other areas, we begin to understand the importance of control in every area.

The final storage tank becomes more and more important in the area of vapor recovery. There are, however, such a broad range of conditions relating to these final storage tanks that no simple or

easy solution exists in every case. The balance or displacement system cannot do an adequate job by itself. The system is, however, basic as a starting point for all effective systems.

Furthermore, no single unit or system can do every type of job. For example, a system capable of handling a service station or car wash pumping 150,000 gallons and up per month is too expensive for use in a service station pumping 20-30,000 gallons per month. By the same token, that service station pumping 20-30,000 gallons would utilize a system too expensive for the CA&I account having a 1,000 gallon tank out in the yard.

There are three basic situations which require treatment. Therefore, three basic systems must be provided. We need one system which will be economically feasible for small stations, one system capable of handling the largest type of installation on an economically sound basis, and another system designed to handle the large middle ground between these two extremes.

We have a system designed for each of the general areas I have mentioned. Each system is priced to be economically feasible for the particular job to be done. The Mark I is a compression refrigeration condensation system designed to take full truck and trailer drops. This system is capable of handling monthly through-puts of up to 300,000 gallons. It is our largest system. The Mark II is a simple carbon canister system designed to handle the small storage tank. This system is sized to process 1,000 gallons of through-put. It is light enough for one man to handle easily. It can be set up in series to handle two, three, or even four thousand gallons of through-put. This is our smallest system. The Mark III is a marriage of the Mark I and Mark II models. We call it a continuous-cycle, self-stripping adsorber. This system is designed for that large middle ground. It will handle deliveries of up to 5,000 gallons, and through-put of up to 50-60,000 gallons per month. To this configuration can be added special designs which are able to handle full truck and trailer drops and much larger through-puts.

Fundamental to the effective operation of each of these three systems are the nozzle interface at the automobile and a vapor collecting system to gather the vapor from automobile tanks as they are being serviced. To accomplish this, we are supplying the Intermark Vapor Recovery Nozzle Adaptor. This adaptor will fit most of the nozzles presently on your pumps and hardware.

There are two vital side benefits derived from a vapor recovery system, other than the contribution to cleaner air. First, any vapors recovered have some value. Properly handled, these vapors can be returned to storage, ready for resale along with the gasoline in the underground tanks. This recovery factor greatly improves the economics of vapor recovery itself. The second benefit, equally important in view of the tremendous energy shortage, is the recovery of energy which is presently being wasted.

A study of our systems indicates clearly that there is a favorable balance of energy saved in comparison to energy used to effect the savings. All three of the Intermark systems are designed to promote both of these benefits.

Our systems are designed to fit into present day marketing and distribution patterns. They require a minimum of changes either at the pump block or in wholesale deliveries. Our systems can, in many situations, make vapor recovery a profitable operation rather than an expense. There is a tremendous job ahead of us. Literally millions of gallons of gasoline are being lost every month, to enter the air as contaminants, while robbing us of much needed energy.

Effecting vapor recovery across the entire United States will require a five-to-seven year program, with many improvements in hardware and methods along that way. Time is short. We cannot afford the luxury of waiting until the final improvement in hardware is made before we begin the job. We must attack the problem today with the tools and hardware at hand. In so doing, we will be making a very real contribution to the quality of life here in our United States. Thank you very much.

V. R. Fusco

The systems that Calgon proposes to offer for control of gasoline service station emissions are very simple. Our control concept consists basically of four steps. Step 1 is the vapor collection common to all systems. Step 2 is adsorption and storage of gasoline vapors in activated carbon canisters. In our approach, this is all the control equipment required at the service station. Step 3 is a periodic replacement of the carbon canisters with regenerated

canisters. Replacement will be accomplished by our technicians driving our trucks on a prescheduled basis. While at the station, they will check system operations and handle any required maintenance. Step 4 is return of the carbon canisters to our central processing site, where they will be regenerated. We calculate that through this recovery we will regain 36 times as much energy as that expended on the recovery operation itself.

At the central site, we will include a large, economic regeneration recovery system based on proven technology. In San Diego County over the past year, Calgon has conducted extensive tests which indicate that this approach can effect up to 98% control of service station emissions at a cost of only a fraction of a cent per gallon. The main feature of our system is that it spreads over many facilities the cost of regenerating carbon and recovering gasoline. This practice reduces the cost of control for any individual station.

I would like to share with you some of the things we have learned in the development of our system and in our test work, which continues in San Diego County. Unfortunately, I do not have time to go into great detail. I will try to hit some of the key points.

As several speakers have noted, the most challenging aspect of controlling service station emissions is collection of the vehicle refueling losses. As we learned yesterday, San Diego's Rule 63 requires collection of all vehicle refueling losses. We have found that total collection is possible only under two conditions. The first condition is a perfect, tight fit with less than 3/10 of an inch pressure imposed on the nozzle filler and interface. The second condition is use of a slight control vacuum-assist.

The first condition represents a tough challenge. Perfect, tight fit is possible only with some modification to the curve in the filler neck. An equally imposing problem is keeping the pressure at the interface below 3/10 of an inch. Excess pressure will result in substantial losses out of the vent line in pre-70 automobiles. For example, in tests we conducted on fuel tanks with 7/32 inch vent lines, about 1/3 of the vapors generated during refueling were lost out of the vent line when 3/10 of an inch pressure was even slightly exceeded. To keep the pressure drop in the vapor return system below this small amount is nearly impossible. We must conclude that vapor collection efficiencies will be very poor in any forced displacement schemes considered for pre-70 vehicles.

Use of the vacuum-assist for collecting vehicle refueling losses has been a sincere concern to oil industry representatives. We have therefore taken great care in our test work and in the design of our systems to incorporate vacuum-assist judiciously. First, we have developed a vacuum-assist system which pulls a vacuum of something less than half an inch of water. Second, we control the amount of vapor flow by using a vapor proportioning system in the vapor return line. Third, and most importantly, we control the timing of vacuum-assist so that vacuum is never induced on the nozzle unless liquid is being dispensed.

In addition to these developments, Calgon is incorporating some features in experimental nozzles which we feel are important. We collect vapors inside the filler neck, rather than at the interface, where air leakage can occur. We have found we can better control the degree of tight fit on the inside of the filler neck. There we found less pressure variation to contend with than at the interface.

With the combination of these simple nozzle features and a vacuum-assist, we believe the goal of total collection of vehicle refueling vapor losses is attainable at relatively low cost per station. We have found that once all auto refueling losses are collected and displaced back to the underground tank, about 80% of the vapors generated during refueling are controlled by displacement. We have gotten essentially the same result by using forced displacement in post-70 cars, vacuum-assist displacement in pre-70 cars, and vacuum assist displacement in mixtures of post- and pre-70 cars. Our results are comparable to the Phase 2 Scott Research-CRC study. The remaining 20% of the vapors not controlled by displacement are picked up with a carbon canister on the vent line. Simultaneously, this same canister handles excess underground tank filling and breathing emissions.

For larger stations we propose total displacement plus a single carbon canister. For smaller stations we propose another system with a much lower investment. Instead of displacing auto refueling losses back to the underground tank, we propose to collect and displace vapors directly to a carbon canister located on, near, or underneath the pump island. In this way, some \$1,500 worth of trenching and piping can be eliminated at the station. We further recommend the installation of an above ground vapor balance system for the truck drop and the use of a separate carbon canister

as required for losses from the storage tank when our trucks visit the station. Both canisters can be replaced simultaneously. Our studies indicate that for a small user, this system is a more economical, cost-effective approach than is a vapor balance system.

Calgon is in the process of installing and demonstrating the two systems I have described in some forty service stations in San Diego County. Our primary objectives are to get more technical experience and pin down control cost economics. The test stations range in size from those dispensing only 300 gallons of gasoline per month to those dispensing in excess of 100,000 gallons.

We are implementing this program entirely at our expense, a fact which indicates our confidence in this approach. Furthermore, we plan to have our systems checked by independent agencies to confirm that we are meeting all pertinent safety considerations. We don't claim that all problems are solved nor that the gods have given us insight into all of the solutions. We are trying in an objective and scientific manner to develop a convenient, reliable, and economic solution to this problem. If successful, we plan to install these simple systems and offer the periodic regeneration service for a nominal monthly service fee. The station owner will have no initial investment to make. Thank you very much.

VI. A. Datis

Good morning, ladies and gentlemen. Process Products is pleased for this opportunity to present its vapor recovery system, called Vapor-Savor, as well as its new nozzle modification kit.

This Vapor-Savor, in Figure One, has a refrigeration system normally operating at 10°F to reliquify hydrocarbon vapors. The refrigeration system runs continuously at 10°F while controls are intermittently sensing tank pressure. After a given period, if the tank pressure is in excess of 2 inches positive, which is an indication that the non-condensable gases are in the storage tank, the Vapor-Savor automatically secures its blowers, permitting the refrigeration system to reduce coil temperature to minus 40°F.

The transient period from plus 10° to minus 40° is what we call the soak-cycle. Once the soak cycle is completed, we then permit vapors to exhaust from the storage tank over our minus 40° coil prior to being vented. As the vapors pass over the coil, sufficient hydrocarbons precipitate, resulting in 10 percent or less of the hydrocarbons being vented along with the non-condensable air.

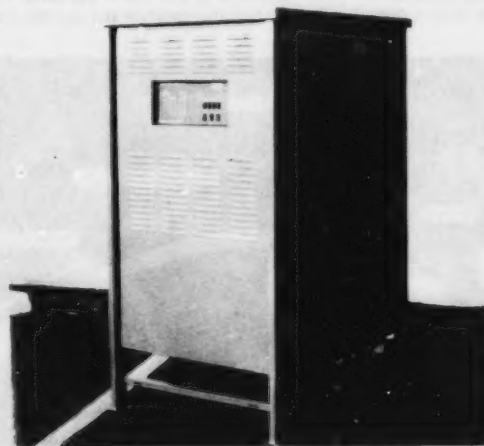


FIGURE 1.

Solid state controls operating on 24 volts are used to sequence the operation of the Vapor-Savor. The control panel can be seen in the center of the Vapor-Savor. Electronic logic has been designed into the control system to start the Vapor-Savor automatically when tank pressure is two inches above positive. The system then commences with automatic sensing of the tank pressure every 30 minutes and, if necessary, enters the soak cycle, which is a prerequisite for venting. During venting, gases between the temperature range of minus 20° and minus 10° are permitted to vent. This too, is automatically regulated by the solid state controls.

Physically speaking, this Vapor-Savor weighs approximately 700 pounds, requires a floor space of 38 inches by 44 inches, and is 73 inches high.

GASOLINE STATION VAPOR RECOVERY SYSTEMS

OPERATIONAL SPECIFICATIONS (Maximum Capacity)

VAPOR-SAVOR	Throughput/ Month	Nozzles Operating	Each Dump Gallons	Dump Rate	Dumps Per Day
200	200,000 Gal	12	8,800	800 GPM	2
400	400,000 Gal	24	176,000	1,600 GPM	2
600	600,000 Gal	36	264,000	2,400 GPM	2

PHYSICAL SPECIFICATIONS

VAPOR-SAVOR	Refrigeration Capacity*	Current @ 230 Volts	LxWxH, Inches	Weight, Pounds	Control Voltage
200	25,000 BTU/HR	35 amps	44x38x70	685	24 v.
400	50,000 BTU/HR	68 amps	80x43x76	1160	24 v.
600	75,000 BTU/HR	99 amps	78x50x79	1570	24 v.

* Capacity at 20 deg. F.

FIGURE 2.

In Figure Two we have the specifications for the three Vapor-Savor models, all operating on a sequence just described. The difference in the models is primarily the permissible number of volt dumps per day. On the Vapor-Savor 200, for example, two dumps per day of 8,800 gallons per dump may be made as long as the dumps are not simultaneous. On the Vapor-Savor 400, a dealer may have four dumps per day, once again not simultaneously. On the Vapor-Savor 500, six dumps per day may be made.

Now I would like to take a few minutes to concentrate on the important portion of our system, the nozzle modification kit.

Process Products feels it has made a significant advancement in the state of the art with the nozzle modification concept shown in Figure Three. The controls for the nozzle performance are located in the dispensing unit where they belong and not in the hands of the service station operator. By locating the controls and the electronics

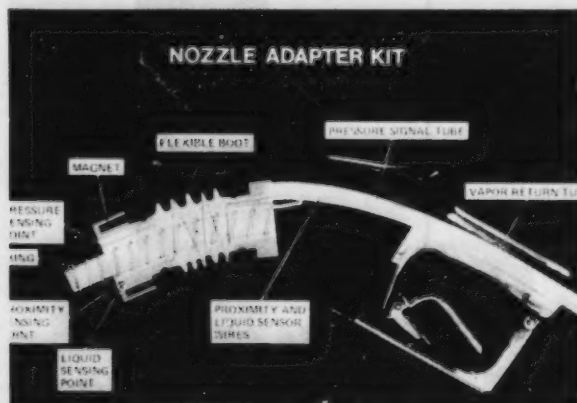


FIGURE 3.

at this point, we remove from the nozzle any moving parts, linkages, or components that will be damaged by carelessness.

Our nozzle features three concepts. First, we have very accurate control of pressure. For example, plus or minus 10/1000 of an inch of water. Second, we offer a liquid sensor that detects the presence of liquid and even super-saturated vapor, if necessary. Third, we include a proximity switch that will permit the nozzle to pass fluid only if it is in direct contact with the gasoline tank.

The sequence of operation of the nozzle is as follows. First, the proximity sensor must be in contact with the tank before liquid can be pumped. This assures that the bellows will be in contact with the automobile tank and, as a result, the vapors will have the best possible chance of being captured. Once contact is made at this point, our electronic logic permits the station's gasoline pump and vapor return pump to start.

Second, the tank pressure in the automobile will be kept at 50/1000 of an inch of water negative by a regulating valve controlled by our solid state controls. In the event that the vapor return hose in the system is kinked and will not permit vapors to be recovered, automobile tank pressure may increase. Our solid state control system will sense this pressure rise, and at 1/4-inch positive pressure, will secure the gasoline pump, thus avoiding any spillage. Restarting of the gasoline pump will simply require the return line to be cleared of any blockage, thus permitting the tank pressures to again reach 50/1000 of an inch negative. I would note that the service station attendant has manual control of the nozzle flow rate at all times while the proximity sensor is in contact with the automobile tank.

The third feature of our nozzle is a liquid sensor. This liquid sensor is highly sensitive and will detect liquid or droplets of gasoline vapor as they pass through the vapor recovery line. Once our sensor detects any amount of liquid reaching the nozzle, it will automatically secure both the vapor return regulating valve and the liquid pump. To restart pumping requires reinserting the proximity switch by removing the nozzle from the car by one inch and then reinserting. We feel this device will be of prime interest to the department of weights and measures, since our system will not permit a customer to pay for gasoline on one end while it is being removed at the other.

I would like to point out that the Vapor-Savor will operate with any nozzle using vapor-assist. This is because of our venting capabilities. Conversely, our nozzle will work with any vapor recovery system on the market because of solid state controls which are completely independent of those controls used on our Vapor-Savor. Because of the accuracy of our nozzle controls, our nozzle will suck in less air to the tanks and therefore can increase performance of recovery units that are sensitive to too much air or to those systems which do not have venting capabilities.

Finally, I would like to discuss safety. Our vapor recovery system, first of all, has been built with a 24-volt control system. We have complied in every respect with electrical and safety codes. We feel our machine will pass the scrutiny of all inspectors. To date, we have reviewed our system characteristics with the fire marshal, electrical inspector, and building inspector, and in each case we have received preliminary approval of the design and manufacturing techniques. Thank you.

DISCUSSION PERIOD

MR. BRATTAIN: Thank you. I have been listening to the presentations, and I think that several of the speakers have confirmed that these systems provide a cost-effective method of preventing hydrocarbon emissions to our atmosphere. I think we generally agree that this system saves a significant amount of energy at a moment when we very much need the energy.

There do seem to be, however, some disagreements. I think one of the problems facing us involves this subject of fill pipes. Everybody up here has emphasized the idea that fill pipes on present cars represent real difficulties. I know that we have at least one gentleman in the audience who would like to comment on this point. Mr. Walker, would you like to make a few comments?

MR. BROOKS WALKER: Walker Research, San Francisco. I own the patents on the carbon canister designed for use in automobiles.

Consideration should be given to use of retrofitting adaptors on used car fill pipes. These could be designed to match the hoped-for

standardized cap and tiller neck for new cars. Such a device would afford the requisite opening for the new vented filler nozzles. The cost for this used car retrofit would be reasonable.

MR. BRATTAIN: Do you have any particular ideas as to how this could be done, Mr. Walker?

MR. WALKER: I think the adaptors would need only to extend out about 1/2 or 3/4 of an inch. Some cars having a flange and a fairly flush filler neck, like the Jeep Wagoneer, could be adjusted with spacers to give room for the new adaptor. I have only made a few samples, but I think they are a fairly easy construction. As I said, the financial burden to the used car owner would be reasonable.

MR. BRATTAIN: Thank you. I think the subject was brought up yesterday by Mr. Simpson, who spoke for Ford. He thought that having adaptors in the station would be impossible. Any further comments?

MR. FUSCO: I have already stated that we don't have all the answers. A private inventor named Al Wokas in Michigan, however, has developed an internal bushing made of a material totally resistant to gasoline vapors. This bushing can be installed in cars for something less than \$1.00 per filler neck. The inside diameter of this internal bushing would be slightly less than the outside diameter of the vapor return sleeve on a standard nozzle. Insertion of the nozzle through this bushing in the car provides a tight fit.

We have been quite intrigued with his thinking and his materials, and we are working with him on the development. From a technical standpoint, we see absolutely no problems. From the administrative standpoint, however, we wonder how to get the proper ordinances to install such bushings on cars, particularly in localized regions. We have discussed this problem with local air pollution control agencies and with the California Air Resources Board. Like so much else in this vapor recovery area, on this point no one has the answers because everything is so new.

MR. BRATTAIN: Thank you. We have seen at least one nozzle that apparently expands inside the present filler pipe. Jack, I would like you to comment as to what size filler pipes you have been successful with.

MR. GÖCKEL: The expanding annulus will fit any opening between 1-3/4 and 2-1/8 inches. Since we are using vacuum assist, however, the seal does not have to be tight. Our limited experience with the nozzle does seem to indicate that we could probably get very close to a tight seal on about 70% of the cars.

MR. BRATTAIN: Thank you. Although not an expert in this field, I feel that the question of controlling vapor losses during loading of service station tanks is much closer to what we might think of as a satisfactory condition. The only particular problems I have heard over the last few days are the questions of liquid loss on disconnection, whether the attendant delivering the gas hooks up the return line, and a question this morning on whether or not we should standardize on a larger hose so that putting in valves to prevent liquid loss would not cut down the actual through-put area. Do you generally feel that this area is fairly satisfactory now? Mr. Percy, do you feel the situation is satisfactory?

MR. PERCY: Union Oil has offered the County of San Diego immediate recovery of vapors from the underground tanks. Our applications have not been processed, and we don't have a permit to go any farther. But we were willing to do so while the other necessary technology was developed.

Union Oil is in the process of installing in Los Angeles County one of the systems described this morning. We started 2½ weeks ago and are somewhere in the process of completing the first 100 service stations. If a terminal has a vapor recovery system which brings these vapors back, it is a working system.

MR. BRATTAIN: Would you care to comment on the idea that we ought to standardize on larger hoses so that we could put in cut-off valves to prevent liquid losses?

MR. PERCY: The required system which Union helped pioneer in Los Angeles County has a half-inch vent open to the atmosphere. As long as you have that tank at atmospheric pressure, there is no need to put in a dry-break coupling. Therefore, I do not see any reason to put in bigger pipes. This system is open to the atmosphere anyway.

MR. BRATTAIN: Thank you. Does the gentleman in favor of the larger hose care to reply on this matter?

MR. SLAWINSKI: The only comment I would make at this time is that the State of Connecticut requires a closed end system.

MR. LEE SINCLAIR: San Bernardino Air Pollution Control District Engineering Staff. I would like to pose a question to the

panel. Considering the fact that there will be many areas in California requiring vapor controls at the filling stations, when will production of the necessary equipment components be at the point where we can fairly impose these requirements?

MR. BRATTAIN: Are you referring to the actual tanks on the vehicles?

MR. SINCLAIR: I am referring to both controls on the dump situation and the car-filling situation.

MR. BRATTAIN: All right. Let's divide this question and have it answered first by the equipment suppliers. When do they feel that the equipment will be available for control of vapor losses during truck dump?

MR. CISCO: We are presently in production on the concentric coupler and adapter we showed you. This system initially will be installed in San Francisco and San Diego Counties by Standard Oil of California. All we really need are orders. We have a lead time of about 90 days on any reasonable quantity from this point.

MR. DECKER: We have that equipment in stock. We can ship 1,000 pieces tomorrow.

MR. JOHN DEWITT: A question to the regulatory agencies. I am President of the California Oil Marketers Association. How soon will these pieces of equipment, some of which are prototypes, be approved by the various regulatory agencies? The smaller marketer, who is not supported financially by a major oil company, cannot afford to commit his resources until he is certain the equipment will meet necessary standards.

MR. BRATTAIN: I think that is a very good point. It brings up the question of whether there are still safety hazards connected with any of the underground filling operations. Are these systems that you two gentlemen spoke of actually approved? Do they have safety approval, weights and measure approval, and so forth?

MR. CISCO: In answer to your question, we haven't talked to the weights and measures board but we see no reason why they should be involved in underground filling operations. They would be interested in automobile filling. This is a transfer of vapors from a tank truck delivery to the underground service station. It is no different from what it has always been—except, as someone in the audience reminds me, when independents are involved. That is a good point.

MR. BRATTAIN: Apparently we remain with a weights and measures question. Is the audience satisfied on the underground dump situation? Or are there further questions?

MR. HEMMEN: Union Oil Company. We have been talking, I believe, about the dump to a service station underground tank, where large quantities of gasoline are discharged from transports. This discussion could also apply to major customers with similar sized tanks. I have yet, however, to see anything that provides for the small customer. I am speaking of the so-called commercial or industrial account with a 2,000 or even 1,000-gallon tank. Do any of the equipment manufacturers have anything to say concerning this aspect?

MR. BRATTAIN: I will have that question answered as soon as I have this man respond to the previous question.

MR. WIVER: Shell Oil Company out of Houston. To follow the question of the gentleman from San Bernardino as it pertains to UL clearance, when is this equipment going to be tested and available in quantities that we need? I am not talking about one piece of equipment, but about a hundred thousand pieces.

MR. BRATTAIN: That is a question we certainly have to get to. But let's handle this question on availability of equipment for filling the underground tanks of the small 1,000 or 2,000 gallon customer. Anybody on the panel?

MR. TAYLOR: In our system, the Mark II simple canister system, and similarly in Calgon's system, we may have the solution to this particular problem.

The Mark II single canister is sized for handling by one man for easy exchange of a stripped canister with a filled canister. It is capable of handling the 1,000-2,000 gallon through-put. Our unit, as I mentioned, can be set up in series to handle the 2,000 gallon tank or 3,000 gallon or even 4,000 gallon throughout. In actual operation, it could be set up to handle any type of volume.

The reason we chose single, thousand-gallon increments is that we believe the wholesale distributor and the independent oil jobber belong in this business. With our system, they will be able to strip and provide exchange canisters with their smaller deliveries. Finally, we feel our system has a very reasonable cost for solving that particular problem.

MR. LEE: I indicated during my presentation that we have a

model Vapex 400 that is basically designed for any partial drop. I mean anything less than roughly an 8,500-gallon drop. Our system is a little different from the other systems in that while we do use a carbon canister, we regenerate it onsite. There is no need for replacement of the canister or returning it for regeneration. Our unit is priced pretty reasonably, I believe.

MR. HENRY MAYERSOHN: Air Resources Board, State of California. Most of the legislation being proposed today, as well as some of the existing legislation, exempts such small tanks from these regulations.

I do have a question for two members of the Board, if I may. As a task force member of the EF-14 project, I have had an opportunity to see most of the equipment that has been discussed this morning. I would like to ask Mr. Gockel and the last gentleman who spoke where I could see their equipment. Is either unit installed at a real life service station? Do you have any test data?

MR. GOCKEL: Our unit is being installed at the Triggs Street station at the Union Oil Company Office on the Santa Ana Freeway.

MR. LEE: We have approximately 15 installations scattered around San Diego County. There are about nine in actual operation, one of the which has a history of three to four months continuous operation with adequate performance. A number of our installations are located on top of the roof.

We have one station within the City of San Diego, located near the Miramar Naval Base. This one is a Model 1500, capable of a through-put of 60,000 gallons a month.

MR. ANGELO: Datis, Process Products. You can see the Vapor-Savor in our plant and hopefully in San Diego within the next week or two.

MR. PAUL TALLY: I am with Audiomagnetics Corporation in Irvine. We are industrial users of hydrocarbons, toluene, and ketones. One of the ketones is an exempt solvent so I assume we don't have to worry about it, but the other is not. We want to know, of course, whether the adaptors work for these types of solvents. Will the same principle be involved in filling our tanks as in filling gasoline stations. Thank you.

MR. BRATTAIN: Would anyone on the panel care to comment on that question? Mr. Lee will speak.

MR. LEE: Our system mixes the hydrocarbons with air and catalytically converts them into CO_2 and water vapor. There is no reason why we could not oxidize toluene. The answer your question is that oxidation of organic chemicals is identical to the oxidation of hydrocarbons.

MR. BRATTAIN: I am sure that the equipment that handles gasoline will handle toluene with the degree of aromatics we have now. I am not sure whether you are going to run into any difficulties with any of your connections. I am not familiar with the details of connections of the ketone system.

Are there anymore comments on underground tanks?

MR. BOB SILER: Verick, Incorporated. Something we have not yet discussed is the gauging of underground tanks and the vapor loss that is created when the hatch is opened.

MR. BRATTAIN: Do you have a comment on the problem or is this something you would like people to comment on?

MR. SILER: I would like to have some people comment. This question especially concerns vapor recovery systems where a closed system or a drop system is being operated. Here pressure builds up inside the tank with approximately 20% of the created vapors, until the half-inch bleed valve reduces the pressure in the tank to atmospheric.

MR. BRATTAIN: What about this problem? When you gauge the tank immediately after filling it, you might find an appreciable vapor loss. Does anybody care to comment?

MR. PERCY: The gentleman was indicating that you could gauge through the drop tube. You would not be releasing vapors because the tube is sealed by liquid at the bottom. You would not get an accurate gauge, however, because the upper part of the tank would not be at atmospheric pressure. Therefore, the level in the drop tube would not necessarily reflect the accurate level in the tank.

MR. BRATTAIN: This may still be a problem. We would not lose vapor, but we would not be getting an accurate gauge, either.

MR. SINGH BAJWA: From Washington, D.C. I have a question for Mr. Leiferman, the first speaker. There was some reference made to the efficiencies of these systems. Some speakers said that displacement method can get only 75% to 80% efficiency. Mr.

Leiferman mentioned that the system could go as high as 90% plus. I would like to hear some comments on that.

MR. LEIFERMAN: In the part of our study concerning underground tank filling, we demonstrated about a 95% vapor recovery during the actual dumping process. This percentage does not include any small amount that might be lost during diurnal changes. The smaller recovery percentage that other people spoke of included vehicle filling statistics along with the underground filling statistics.

MR. BRATTAIN: That is my impression also. I think the speakers were in pretty good agreement that recovery on underground tanks was quite high.

MR. BOB LINDBERG: J. E. DeWitt, Inc. Mr. DeWitt asked the question concerning approval of these systems. I don't believe we got answers. Are we using a system in L.A. County? Has it been approved? Are all the systems now being used approved?

MR. BRATTAIN: The gentleman from the National Fire Protection Association said that fire safety approval is up to the local jurisdictions. There is no such thing as national approval by any fire protection association. The answer to your question is that local approval has been granted.

The second question involves possible approval by the weights and measures bureaus. Weights and measures can be approved on a state level, and then be administered on a county level. I do not believe, however, that approval by weights and measures is necessary.

MR. MILES WOODWORTH: National Fire Protection Association. You quoted me correctly regarding information on the NFPA standards. Legal approval is up to the local jurisdiction. I should quickly point out, however, that in most jurisdictions the authority involved—say, the city or state fire marshal—will rely almost completely upon Underwriters Laboratories or some other nationally recognized testing facility.

MR. BOB HERSHBACHER: Underwriters Laboratories in Northbrook. I think I can provide the audience with an explanation of which authorities or agencies might have approved equipment used in filling service station tanks and which are involved in regulations relating to the filling of automobiles.

Underwriters Laboratories has not been approached by industry to investigate equipment from the bulk plant or the service station tank. I do not mean we would not conduct such an investigation, but we have never been approached. As a result, we have no submittals of any of this equipment.

To answer the next question, which, Mr. Chairman, you were going to ask very shortly, I will describe what is being done by Underwriters and other agencies in the system concept and in the nozzles. We have quite a number of submittals from manufacturers of systems and nozzles. We do not yet know when our tests will be completed. Most of these submittals have come within the past month. People may have been working on the concepts for years, but Underwriters Laboratories needs the actual hardware for testing.

We are now at the testing point. The manufacturers have developed equipment and have samples that they can send to us. We hope to complete some of these investigations within three to four months. Normally, our test work can be completed six to eight weeks from the time that all samples and information are received. These systems, however, are new concepts to our laboratories. We have to develop new programs. Finally, tests will probably require submittal to our fire council for approval of our actions.

MR. BRATTAIN: Thank you. That was a very helpful contribution.

MR. DATIS: We contacted the UL labs about three or four months ago when we first began developing our machine. We mutually agreed that our company should first get some run time on the machine, to make certain that the design we gave to UL would be the final one.

MR. BRATTAIN: Thank you. The Chairman is going to make the arbitrary decision to discuss the filling of tanks on automobiles. We don't want to spend too much time on underground tanks. Would you gentlemen care to ask your questions now?

MR. JOHN CALCADME: Environmental Protection Agency, Region I in Boston. With regard to either the underground or the tank systems, do we have any experience data for their function in inclement weather—in a worse climate than that found in San Diego, I mean?

MR. BRATTAIN: Have any of you gentlemen had any experience in Detroit or Minnesota or anywhere like that?

Apparently no one has.

MR. CALCADME: Would you like to comment on any potential problems you perceive from a theoretical viewpoint?

MR. BRATTAIN: Jack Keller?

MR. JACK KELLER: Representing the American Petroleum Institute, I am chairman of the API Task Force EF-14. I was going to make an announcement this afternoon, but perhaps I might intrude on your time to answer the gentleman's question.

We have not had experience in the kind of climate that he is speaking of. Last Thursday, however, the Committee on Environmental Affairs approved an expansion of our program so that we could study three service stations in areas in Chicago and New Jersey. While these areas might not get as cold as Boston, they still can get pretty cold. We should obtain the necessary experience, hopefully by the end of February.

MR. BRIAN GIBBONS: Husky Oil Company, Denver. I want to know whether we can see any of the equipment talked about this morning. Are we going to see any tomorrow during our tour in San Diego?

MR. BRATTAIN: Bob, why don't you answer that one?

MR. ROBERT COIT: I cannot give you a specific location where equipment can be viewed tomorrow. However, Mr. Schell has the tour designed to visit not only the county garage, where some equipment is installed, but also other service stations in the area. We will see a cross section of the types of equipment which are involved. If you go on the tour, you will see some installed equipment. Now whether you will see it in an operating condition is perhaps a question.

MR. BRATTAIN: There is one point I would like to hear some questions about. This morning we heard some disagreement on whether secondary recovery or vacuum-assist is necessary, or whether simple displacement will work on the automobile tank. Mr. Gockel calculated that although displacement is the most cost-effective, secondary recovery is 1½ times as cost-effective as our retrofit program on NOX. I think he also said that secondary recovery is three times as effective as the controls presently on new cars. Yesterday, Mr. Simpson made essentially the same statement. Mr. Leiferman started out on the displacement side, saying that he thought he was getting in the neighborhood of 90% recovery. Mr. Gockel felt that he was getting only about 75%. Would you care to make any further comments on this?

MR. LEIFERMAN: Well, not really much more than I have already. We ran actual tests with several cars and looked at several underground deliveries. We saw an average recovery of approximately 90% for hydrocarbons at service stations. I believe these figures are valid. As far as diurnal losses go, there is such a very small change, if any, in temperature of the underground storage tank that we would expect, on a theoretical basis, essentially no hydrocarbon loss from that occurrence. I might add that we left the carbon canister on the underground tank vents overnight to see if any outbreathing occurred. In no instance did we find any hydrocarbons collecting in the carbon traps during the night hours.

MR. BRATTAIN: Do you feel that this 90% recovery could still be realized in an actual service station environment? I remember that you noted a couple of cases in which you didn't get any vapor recovery at all.

MR. LEIFERMAN: We told an experienced service station attendant to fill these vehicles as he normally would. In no case did he hand hold the nozzle. At no time did he try to force the nozzle or position it. That is the way he operated.

Now I suppose that with us standing around taking data and observing him, he might have taken a little bit more care than he normally would have. I don't know. But we think that test conditions were very close to statistical service station operating conditions.

MR. BRATTAIN: My general experience has been that people who worked for me worked a little better when I was standing there.

MR. GOCKEL: I would like to explain where I got the 75% recovery. Our results are half way between Mike's data and San Diego's data, I think. Mr. Fusco's data may also indicate that 75% recovery is more nearly correct. I think you indicated that API's results were closer to what you were getting. But I feel that diurnal losses will be affected by temperature. They will also be affected by barometric changes. Our calculations show that the barometric changes will have more effect than the temperature changes, particularly in other parts of the United States. Apparently we don't

have a wide variation of barometric pressures on the West Coast, but in other parts of the country they could vary substantially. Our figures show something like a 3% loss for diurnal.

We think the total loss of vapors in a service station include a 5% excess on filling the underground storage tank and a 10% excess on filling the vehicle tank. San Diego is reporting this figure for its vehicle filling operations. If you proportion those figures on a 40-60 basis, you come up with 7%. Add this figure to the 3% diurnal loss and you have a 10% loss. Furthermore, we think the current state of nozzle technology points to a tight fill. Perhaps 70% of the vehicles could get a tight fit, and some vehicles not at all. We could have a 10% loss there as well. Older, unequipped vehicles would have further external vent losses of about 6%. We compute total losses to be 26%. If we are wrong by a factor or two, then we are talking about a control strategy for hydrocarbon control roughly equal to what we are doing now in the used car control program.

MR. BRATTAIN: Jack, what do you mean by the San Diego data? You said that your 75% figure was half-way between what Mike found and what San Diego found. Perhaps Mr. Schell could comment.

MR. SCHELL: Yes, San Diego has data in this regard. I might say that the 20% excess vapors figure did not include the pumps. We included only the drop and losses from the nozzles. Our experience has been far different from that expressed here with respect to a 5% loss. Our data are available. Calgon, whose data was referred to a little earlier, also reflects excess vapor results which are different from the results reported here.

MR. BRATTAIN: I think Mr. Fusco of Calgon would like to comment.

MR. FUSCO: We conducted a test from December 4, 1972, through February 8, 1973, at the fleet operations division service station of the County of San Diego. I have here a copy of our test report. We did a substantial number of auto refueling loss tests. I think I mentioned in my brief presentation that we started with forced displacement tests in post-70 cars. We also conducted vacuum-assist displacement tests in pre-70 cars. Finally, we did vacuum-assist displacement tests versus forced displacement tests in both pre- and post-70 vehicles. In addition, we conducted three underground tank filling tests and 10 diurnal breathing loss experiments.

Our total experience was basically this. On all our truck drop tests, we got 90% recovery through displacement of underground tank filling losses. Diurnal breathing losses were constant at about .01 pounds per vent per hour. This checks out well with calculations made using API storage tank loss equations based on the ideal gas law. On auto refueling, we had losses ranging from 5% in some controlled experiments up to 100% excess losses. The 100% cases occurred when we purposely pulled a high degree of vacuum or allowed some air leakage to see if emissions were increased. Overall, discounting these extremes, the average control of auto refueling loss via displacement was 75%. We found that a total displacement system would effect between 80% and 85% control, with 100% vapor collection of auto refueling losses, under conditions which will not increase emissions *per se*.

MR. BRATTAIN: Thank you. Mr. Taylor would like to make some comments.

MR. TAYLOR: Intermark. Just to reaffirm what Mr. Schell has said, I was present along with oil company representatives at several truck and trailer drops into underground tanks where one of our pieces of equipment is installed. Both field marketing and research people were present during the drop, when we actually generated, using a balance system back to the tanker, well over 20% excess vapors that did not go back into the tanker during the drop period. On every occasion we have generated in excess of 10% of the vapors, or an equivalent amount in terms of the measurement on the accumulator bag of vapors.

We are convinced that in addition to all the supportive data prior to the more recent tests, actual visual checks of our own installations as drops have been made show generations exceeding this 5%.

MR. HARRINGTON: Shell Oil in Houston. I would like to ask again the question my colleague asked. One of the things we are worried about is the number of service stations that now come under laws which require systems for the refueling of vehicles to be implemented within three to six months. We heard yesterday that Los Angeles and Orange Counties are thinking about such a program. The question that I would like to ask you people on the panel is: What position are we in with regard to actual production

type nozzles? Will we have workable equipment in sufficient quantity?

MR. BRATTAIN: The answer to this question ties in with something that I was going to bring up next. Where are we on the question of refueling vehicles safely? Does anyone care to comment?

MR. DICK MCKERNEY: I am with A. Y. McDonald, a nozzles manufacturer. The concern just voiced is one of our concerns, too. We are a manufacturing company, a substantial one, of equipment. We know only too well that it is a far cry from proto-models—even working and efficient proto-models—to the final production type of equipment. I rather seriously doubt that the state of the art, particularly involving vehicle vapor recovery, is far enough advanced to come anywhere near having the actual production equipment necessary to meet some of the California regulations.

MR. BRATTAIN: Let's have some of the nozzle men reply to this question.

MR. GLENN MOORE: OPW. The first nozzle I showed you, the 7VR, was a prototype nozzle built at the test bed unit to test a number of aspects in vapor recovery. We have since decided not to go into production on the nozzle, because it was experimental. The second nozzle that I showed you, the 7V nozzle, exists only in a few prototypes. This nozzle has been used in some of the tests mentioned today by the oil companies. We have talked to Underwriters Laboratories and, as Bob Hershbach mentioned, there are no specific requirements set as of this date.

One problem regarding safety that hasn't been mentioned, and it has to do with Underwriters, is the problem of OSHA. The requirement covering nozzles and automatic service station nozzles, among others, has been taken from NFPA Code 30 and does require Underwriters listing. This is a national standard. We are in a somewhat difficult position, in that we know what we feel a nozzle should be from our experiments. And certainly Underwriters has to be satisfied if it is to maintain the reputation for safe devices that it has.

After the nozzle design has been approved, with much more field testing than we have done to date, we will have the problem of building production tooling to make the nozzles in substantial quantities. Production requires a great deal of time.

MR. BRATTAIN: How much time does production require?

MR. MOORE: Production will require at least six months because of the die casting, die stamping, dies, and rubber molds required. After that, we will need time to build available materials. This group is aware of the petroleum shortage. There are other material shortages that will be factors. A great deal of time will probably be required for the entire program.

MR. BRATTAIN: Do some of the nozzle manufacturers want to contradict this opinion?

MR. TAYLOR: Yes, I do. We build our own prototype nozzles and built the hardware to build them with. We are ready for mass production. We are waiting for orders. We were getting those orders until San Diego supervisors held a public hearing to discuss extending their deadline. The orders stopped coming in. As a result, no work will be done in production by any supplier until he has an assured market. We don't mind competing for a market, but when the market is shut off, we can't afford to build the hardware.

We are ready to build 1,000 nozzle adaptors. We can build 1,000 of them a month, to fit your existing hardware, within two months of being in production. We are also ready to build hardware, 600 units a month of the three systems that I mentioned, within a three-month period. We have the reserves of supply components nailed down and held for us, pending the results of the December 10 meeting in San Diego and the December 11 meeting in Orange County. If we don't have a viable situation after that, we will have to release the hardware because we will not be using it.

MR. BRATTAIN: I would like to second what Mr. Taylor has said. I am not one of those people who is an ecological hypochondriac. But I have been in the air pollution business for a long time, and I have found that there is a remarkable correlation between what our technology accomplishes and the rather strict goals that are set for it in the form of regulations.

MR. DEAN MCGAHEY: Texaco. Mr. Taylor and some of the other panelists have talked about adaptors and modifications to presently approved nozzles. I wonder if Mr. Hershbach would comment on the effect of adapting or modifying nozzles to the existing approval.

MR. ROBERT HERSHBACHER: I will be glad to. We have, within the last year, changed our policies considerably at

Underwriters. In the past, we tested only new equipment. We would not let anybody touch anybody else's equipment. New policies and legal authorities, however, have gotten us into the investigation of rebuilt and remanufactured equipment. This research includes equipment rebuilt under a controlled program. This is one of the programs we have established for hose nozzle valves of the normal types. We realize from this vapor recovery program that some of the basic requirements for automatic hose nozzle valves may not exist in the adapted or remanufactured types. We hope to come up with a different type of product, perhaps restricted in its use to certain systems.

MR. BRATTAIN: Thank you.

MR. JACK DALEY: Sav-Mor Oil Company. We are a small, independent marketer of gasoline. I would just like to make some comments to the counties requiring us to buy this vapor recovery system and to the equipment manufacturers.

I have spent some time in San Diego looking at the vapor recovery systems that are in operation down there. As marketers, we will put in the equipment required by the County. I would like to say, however, that every installation I have looked at that has been in operation for some time has rubber diaphragms on the nozzles that have either been missing, cracked, or broken to such an extent that vapor recovery through the vacuum system is about nil. Vapor just comes right out the nozzle. I don't know what the hours on these rubber flanges are, but they must be very minimal. Out of the half dozen units that I see, at least 80 percent have flanges with the rubber section cracked and broken.

A second problem is that the dispensers we have in our existing service stations are of different brands. The nozzles that these people are talking about in some cases don't even fit our dispensers. In a brand new car wash in San Diego, I watched the plumber attach the nozzle to the hose. The nozzle would not even go into the top of the dispenser. It was hanging by the handle. While I was there, two nozzles fell off the dispenser and broke the nozzle sections. This seems a great deal of expense, particularly for the small marketer.

With a vapor hose that is attached to the product hose, the operator has two hoses instead of one. In all of the facilities that I have seen, these hoses are generally connected by a tape. Once again, after a period of time, this tape gets pretty shabby. Being a marketer, particularly one who will be spending a lot of money on this new equipment, I find worn, cheap-looking equipment very unsatisfactory.

Finally, none of these operations seems to have an effective hands-off nozzle. These nozzles almost require the attendant to stand there and make sure that the contact is 100 percent. Once again, we are talking about increased labor. We are also talking about the size of these systems, which seems to me to be fantastic for a small piece of property, not only in square footage but also in height. The noise levels in some of them are very high. I have seen oil dripping from some systems, and I presume that this is condensate running on the drive.

What I am trying to get at is, I think that we are being pushed into some kinds of equipment which in our opinion—and we have seen only some of it—may not be ready for marketers at this time.

MR. BRATTAIN: Thank you. I would like to comment. I do think that some of the nozzles discussed this morning are nozzles that the attendant does not have to watch. Mr. Percy, I will give you about 15 seconds.

MR. PERCY: I would like to speak on behalf of the API program presented yesterday in which there were figures indicating that the recovery on a drop is 95 percent. Scott Research presented these data. Scott Research went out and got the data because there was a feeling within API that even if all the members mailed the data in, San Diego, Mr. Taylor, and various other people wouldn't believe us. But these are true values that we are obtaining with the three-inch vapor return system, not a two-inch vapor line, fitted with a dry-break coupling besides. A 95-percent recovery can be obtained.

MR. BRATTAIN: Thank you.

MR. PERCY: Mr. Fusco indicated, and I lost my figures on his presentation, that API has also showed only 70% return from the vehicle. This is not so, because part of the API program dictated that the operator would use vehicles and nozzles that did interface. I think that some of the API data are being misused.

Another part of this program is the diurnal loss. We have a station where this loss is currently being measured. Remember that operating a service station is dynamic. We are pulling air into the

station all of the time, and we may have fluctuating pressures as a result. The barometer may go up at night while the station is dead, pushing a little more air into the system. During the day, less air will be pushed in because the operator is selling gasoline then.

MR. BRATTAIN: I am afraid we must stop now. I hate to adjourn, because people obviously still have further questions and comments. I do want to thank all of the speakers again. I would like

particularly to thank my co-chairman, Mr. Steen. I am going to turn things over to Mr. Scott now.

MR. SCOTT: I think that we are getting to the meat of the matter. This afternoon I will try to highlight some of the conclusions and unresolved problems we have. We will, hopefully, continue a very spirited dialogue between the audience, the session chairmen, and the speakers. Thank you.

WEDNESDAY AFTERNOON SESSION

API PROJECT EF-14:

A REPORT

by

Jack Keller

First, I would like to thank all the participants, committee members, and co-sponsors for joining this program. I think we have been unusually successful, starting from scratch only two months ago and working up to an attendance such as we have here. Gene Cone did an especially fine job on the publicity for the program.

My announcement concerns an addition to the program for the API Project EF-14. In addition to our winter program, we have received approval from API management to expand into another area. We intend to evaluate additional concepts not included in the original program. As you may know, we included only the four concepts that have been evaluated. We are now going to put out an RFP asking for contractors to bid on the expanded project.

In the expanded project, we will attempt to evaluate performance with regard to practical problems and potential problems that we noticed during evaluations in our Phase Two. Many of the problems discussed this morning have come up during our Phase Two evaluations. Some of these problems have concerned people—that is, actual behavior—and they were not included in the original program. Our expanded study will include this and other areas. Really I can't tell you when we would hope to have this study finished, because it will be open to any and all lines of enquiry.

OPENING REMARKS

by

Carleton B. Scott

Our plan this afternoon is to call on each of the three session chairmen. Each will briefly summarize what he perceived from his particular session, regarding the conclusions reached and the problems remaining unsolved. There will be no questions. Following this portion of the program, we are going directly into Mr. Nichols presentation. After Mr. Nichols has finished, we will take a quick break and then come back here for a continuation of the dialogue which began this morning.

Before I call on the chairmen, I would like briefly to refresh your memories and theirs regarding the objectives that I, at least, perceived at the beginning of our meeting. First, are there any basic regulatory factors we can use to guide us in striving for compliance? Second, what kind of progress are we making in this regard? Third, what are we really doing about safety? Fourth, what are we doing about assuring customers that they are getting what they paid for? Finally, can we really meet the mandated deadlines and the recovery efficiencies? There may be other objectives, but these are the ones that I am more aware of.

CHAIRMEN'S SUMMARIES

I. D. F. Walters

In the Tuesday morning session, before we got into the panel discussion, we set the stage for the presentations with a paper by an EPA man, Mr. Fred Winkler. Mr. Winkler summarized the transportation plans and pointed out particularly the ones which require control of stationary sources—that is, service stations and vehicle fueling. Data from EPA showed that this type of control was the most cost-effective method of several listed. The other methods pertained primarily to automobile tune ups, retrofitting, and catalysts.

I think that when these transportation plans were first proposed, the people developing them were looking for anything they could lay their hands on that would reduce hydrocarbon emissions. In areas like Los Angeles, control required just about everything officials could do. Subsequent events have made some of their programs seem not so far out. My own feeling is that while this control should be implemented on a regional basis, or as needed, the energy situation may require that controls be effected everywhere, just to conserve fuel. Perhaps there are better ways of conserving fuel. I was reading in the paper this morning that Mr. Train, who is the head of EPA, said that we could save half our gasoline if we built cars that got 17 miles per gallon instead of 12 miles per gallon.

After we set the stage, we found there were something like eight states, and several regions within these stations, needing the controls for stationary sources, or service stations and vehicle refueling. We had one topic called current research status, and it was somewhat misnamed. There wasn't much material presented on research.

We heard reports from two API projects. The first was by Mr. Olson concerning controls on the vehicle. He concluded that emission control was technically feasible with a carbon canister about three times as big as the existing one. The system would probably pay out in 10 year, perhaps less, using more up-to-date cost figures. The canister did, however, cause an increase in CO exhaust emissions. The second project supported by API was a testing of three different vapor recovery concepts. This project is not far enough along to have produced any firm conclusions. There was not much information actually presented.

We had two papers presented by automobile companies, primarily advocating control at the service stations. The authors felt that this was the most cost-effective method. They felt that controls on new automobiles could not be accomplished in the time allowed by the Clean Air Act. They thought we could meet standards faster with the service station controls.

We heard then from the SAE Committee. We received a lot of information on organization, but SAE hasn't gotten too much material out, apparently. There are no 100 percent effective systems available at this time. There are some procedures for sampling hydrocarbons in the off-gases of these systems. The procedures will be available in the SAE handbook in 1974.

I would conclude that the necessary technology is here; but there is some disagreement as to whether it is 80-, 90-, or 95-percent effective. I would guess we have about 90 percent. Cost-effectiveness is looking better all the time. There are many hardware problems, but we have an eager battery of manufacturers here, ready to fill the needs of their customers. This availability contrasts dramatically with our experience in sulphur dioxide control, where few manufacturers have been willing to say that they would build equipment with a certain efficiency. That in a nutshell is what I got out of the morning session. Thank you.

II. R. G. Lunche

The session yesterday afternoon included several parts. First, we got the state viewpoint. Second, we looked at the control district experiences. Third, we discussed the safety requirements. Finally, we looked at the weights and measures aspect.

One of the conclusions that I reached from listening to the speakers and the panelists was that control of vehicle refueling is definitely on its way. Both the Environmental Protection Agency and the Air Resources Board are requiring such controls. They put control measures in their transportation plans and their implementation plan for the State of California, respectively. We did find that there are several companies, several associations, and several agencies that have been giving their attention to this problem.

In listening to the panelists, I found that there seem to be some differences in opinion on what type of controls are needed. On one

hand, Los Angeles County, Orange County, and the Bay Area seem to feel that vapor balance systems may be adequate. On the other hand, San Diego County wants to go all the way and has even, in the language of their requirement, used the term, "all." San Diego officials say, however, that although they say "all" and they believe this to be reasonable and enforceable, what they really mean is that if they could not detect any hydrocarbon vapors with an explosimeter, they would consider this to be "all." During the session, we discovered that some stations which supposedly have received permits from San Diego County do have problems with odors near the equipment and with puddles, indicating spillage. Apparently the word "all" may not be taken literally by San Diego.

Other conclusions that might be drawn from the testimony of the three other counties include a simple equipment specification detailing the size of the vapor return line as three inches or larger and requiring a restriction in the vent line from the tank of half an inch. This, they feel, would be adequate to insure a 90% control or better. I understand that again, however, there is some question. Some people said control would not be that high, and other people have evidence and test data indicating such control. In the case of L.A. County, we believe that in some cases control would be as high as 98-99%, depending upon the temperature difference between the liquid in the tank truck and the liquid in the underground tank itself. Perhaps these results also apply to the tank and the vehicle tank.

San Diego County officials apparently have come to a conclusion of their own. What is really needed to make their system work is more cooperation on the part of everybody in development of better materials. Materials for the bellows and some part of the automatic shut-off could be improved. They feel that genuine cooperation in solving these problems is lacking.

I think that a resolution to the question of effectiveness of the various control systems—for example, the vapor balance versus the others—is required. Second, I think we need to take a close look at how much is being recovered by each system, the cost, and what the additional costs for additional recovery would be with each system, as opposed to the vapor balance system. Thank you.

III. R. R. Brattain

I would like to begin my summary by going back to some of the opening remarks I made this morning. I think we agree that service station emission control is the cost-effective method of removing hydrocarbons or preventing their emission. The EPA introduced some findings, and Don Olson came up with some figures which closely agree with EPA's. Jack Gockel also had results which agreed with the previous findings. I do not think that there is any real argument against nozzle control as a cost-effective method for preventing the emission of hydrocarbons. Several people emphasize that this method will save energy, perhaps more energy than will be expended in the system by quite a bit.

I think some people even said, in referring to the bulk plants, that the large bulk plant could actually make money from the system. Consequently, I think we have come to the conclusion not only that we are going ahead due to regulatory action, but also that we should go ahead. I would like to emphasize that we should go ahead because this is a cost-effective method which can be implemented now and which does not depend on the introduction of new motor vehicles.

I would like to re-emphasize the point that waiting to take this action until after we get our new motor vehicle controls—an action that will include a larger percentage of the total hydrocarbon emissions—is not a good argument. What we think of is the mass loading of an air basin with hydrocarbons. Nobody knows whether removing this amount of hydrocarbons would really be a sensible thing to do, if we did have all of our motor vehicles cleaned up. I remind you that we use the linear rollback. I do not know what the proper rollback formula is with regard to photochemical reaction in the air, but I am willing to bet anybody that the true formula is not linear. I don't know from which side of linear the formula deviates, but I know it is not linear. The real reason for implementing this system, then, is that it is a cost-effective measure which we can take to improve the situation now instead of waiting 10 years until the new motor vehicles begin to have a real effect.

During my session, I came to the following conclusions. One of our biggest problems at the present time concerns the fill pipes on automobiles. Everybody agrees that whether using a displacement system or a vacuum recovery system, we should get good, tight seals in the fill pipes. The fill pipe problem falls into two categories. First we have the fill pipes on existing cars. I think that probably a further look should have been taken at the point brought up by Mr. Walker concerning whether it is really feasible, at small cost, to retrofit our cars for some reasonable degree of standardization on fill pipes. The nozzle designers would then have a somewhat easier job. Second, as far as new vehicles are concerned, I cannot think of a logical reason why fill pipes are not standardized almost immediately. I know that some of the automobile manufacturers will object. I have listened to some of their arguments, however, at this and other sessions. I frankly believe, gentlemen, that those arguments are sophistry.

This morning's session also indicated that vapor recovery from filling the underground tanks is in pretty good shape. There are still some problems. But in comparison to the problem of vapor recovery from filling the tanks on motor vehicles, I think the underground tank problem is in good shape. During the discussion this morning, I do not believe any serious questions were brought up. I would say that systems necessary for vapor recovery on the underground tanks could be installed without undue delay. There may be a supply problem, and obviously there is a contractor's question, so installation isn't going to be completed tomorrow. As somebody remarked, there are some shortages other than energy. Nevertheless, if somebody wanted to equip a filling station, he could do so. Apparently some stations are being so equipped. Several of the oil manufacturers said they had contracts out to equip the majority of their stations in the critical basins. Car fueling itself still has some serious problems. I mentioned the fill pipe problem. We saw some prototype nozzles this morning that will, I believe, go a long ways toward a solution. The panel generally agreed that probably the best of these nozzles is usable on 70 to 90% of the present cars.

We had great disagreement this morning over use of a displacement system or secondary recovery. The discrepancy in the data basically concerns the amount of recovery and, as a result, the cost-effectiveness. I don't think there is any real question. The most cost-effective operation is simple displacement. There were a significant number of discrepancies in the various figures showing what simple displacement will achieve. If the system is really going to achieve over 90%, then I think this would be the way most people would recommend that we go. If the system will only get around 80 or 75% recovery, then I think there would be legitimate arguments on a cost-effectiveness basis for going to secondary recovery.

I think this question must be resolved first of all on the basis of some standardized test method for determining what percentage of the vapors is lost. I believe the SAE has designed a test method which, if my memory is correct, they call J1045. Furthermore, we have got to check the cost-effectiveness on a year-round basis. There was discussion this morning that breathing of the underground tanks changes significantly with barometric pressures and temperatures. We have got to compare these methods not only under conditions in San Diego County, but also under year-round conditions in different parts of the country. We should also, as a secondary matter, compare the two systems on the basis of energy saved.

Another question which came up this morning, on the fueling of vehicles, concerned the availability of approved equipment. The equipment must be approved from the weights and measures standpoint and the safety standpoint. At the present time, some items of equipment are available. I do not, however, think that there is a general availability of products. This morning's session did indicate that there are some excellent systems in the prototype stage. I don't think that most of these systems have been sufficiently proved in actual use to assume that they are completely satisfactory. Tests could be completed, however, very quickly if there is the market, according to one of the speakers this morning.

I do think there remains a safety question which we really didn't have a chance to discuss fully this morning during the question-and-answer period. We have to look very carefully at safety, including the possibility of explosive vapor mixtures. Pressure relief valves, some of the cut-off systems, and the deactivation devices that we saw can get around the problems of a flareback of liquid out of the tank and pressurizing a car tank too much. If even a partial vacuum is created on a tank, however, we have to be careful about the vapor problem.

In summary, our session has shown that problems exist. But I think those problems should be viewed as something which we use our energies and our ingenuity to overcome. I do not like the idea that problems have historically been used as an excuse for not doing something, or as an argument to slow things down. I would remind you, gentlemen, that we can always find something wrong or bring up a problem. More difficult is finding the solution. All of you represent a segment of American society which has been responsible for a great deal of progress, and I am sure that we will view the problems as challenges rather than as reasons for delay. Thank you, gentlemen.

INTRODUCTION BY THE GENERAL CHAIRMAN

Thank you very much, Bob. Now we are going directly into Dr. Nichols' presentation. Dr. Nichols is Technical Program Manager at Parker-Hannifin. He has been working for some eight years in the field of vapor control and vapor handling. Currently he is involved with an EPA contract in the vapor emissions field. A good deal of the work he will present today has been in support of that contract. Dr. Nichols.

HYDROCARBON EMISSION SOURCES AT SERVICE STATIONS

by
Dr. Richard A. Nichols

My subject today is various approaches—effectiveness—costs—and technology timing. I am afraid that is a rather broad subject. I propose, however, to discuss all of these areas from a technology point of view. There are three important sources of emissions at

1. SERVICE STATION TANK REFUELING
2. SERVICE STATION TANK BREATHING
3. AUTOMOBILE REFUELING LOSSES

FIGURE 1: Hydrocarbon Emission Sources at Service Stations.

service stations: station tank refueling, tank breathing, and automobile refueling, shown in Figure One.

Let's take the area of service station tank refueling. There are three basic emission process approaches. First, you can process the

EMISSION PROCESS APPROACHES

1. PROCESS VAPORS AS GENERATED
2. RETURN VAPORS TO TRANSPORT AND VENT EXCESS
3. RETURN VAPORS TO TRANSPORT - COLLECT AND PROCESS EXCESS

FIGURE 2: Service Station Tank Refueling.

vapors as they are generated. Second, you can return the vapors to the transport and vent the excess (this is a vapor displacement). Third, you can return the vapors to the transport and collect and process the excess, via secondary recovery.

The first method is hardly ever used except, as we have seen, at small drop places. This is because you are generating such a large amount of vapor so quickly that large process equipment is necessary, and this is just not cost-effective. The second method, vapor displacement, has been used because this is an ideal way to bring the vapors back to the terminal. Here you have process equipment to handle them. The third method is one that you must consider if the second is not efficient enough. At this point, then, we will look at some of the vapor collection programs and what type efficiency is generated from item two.

1. OVERSEAS PROGRAMS
2. IN-HOUSE OIL COMPANY STUDIES
3. W.O.G.A., ORANGE COUNTY APCD AND LAAPCD STUDY
4. SAN FRANCISCO APCD AND STANDARD OIL OF CALIF WORK
5. SAN DIEGO LEGISLATION
6. CORRELATION WORK AT PARKER

FIGURE 3: Service Station Tank Refueling Vapor Collection Programs.

I have identified six basic programs. There have been some programs initiated overseas. In Italy, for instance, operators pick up the vapors at the service station by direct displacement. The vapors are then taken outside of town, I understand, and vented. The idea is not to vent them in town where they can cause a hazard. The same thing was done by Mobil Oil for some time in Japan. Those involved had some problems with this system and, I think, have since either alleviated the problems or stopped using the system. Second, in-house oil company programs were initiated. These, as was mentioned earlier in the program, occurred maybe six years ago. They were initiated because emission regulations were coming, because the system is economic, or because there are certain economic aspects of return of vapors from the filling station. Third, the Western Oil and Gas Association, Orange County Air Pollution, and Los Angeles Air Pollution did quite a number of studies to determine efficiencies of vapor transfer. Fourth, San Francisco Air Pollution—working, I believe, primarily with Standard Oil—has done a vast amount of testing in Standard Oil's Davis facility.

Fifth is San Diego, and here we find a marked change. At this point, we are dealing with more than vapor displacements. The law requires secondary recovery, the way it is written. At this point, there began a large number of programs designed to look into secondary recovery. Finally, we are going to talk a little about the correlation work we did at Parker.

Let's look first at some of the Orange County, Western Oil and Gas Association, and Los Angeles County work that was developed, beginning with Figure Four.

INVESTIGATION AREAS

1. WHAT SIZE VAPOR RETURN LINE IS REQUIRED?
2. HOW DO YOU INSURE DRIVER HOOK-UP VAPOR RETURN HOSE?

PROPOSED LAW REQUIRING:

1. EQUIVALENT 3-INCH VAPOR RETURN HOSE
2. ONE-HALF INCH VENT ORIFICE OR INTERLOCK TO INSURE VAPOR RETURN HOSE CONNECTED

FIGURE 4: W.O.G.A., Orange County APCD, LAAPCD Study.

Investigators were interested primarily in two areas. First, they looked at what size vapor return line is required and second at how they might insure that the driver hooks up his vapor return hose. They came up with a proposed law which requires the equivalent of a 3-inch vapor return hose and a 1/2-inch vent orifice or an interlock to insure that the vapor return hose is connected. We have done some work at Parker which I think tends to verify these conclusions, and we would like to present our findings.

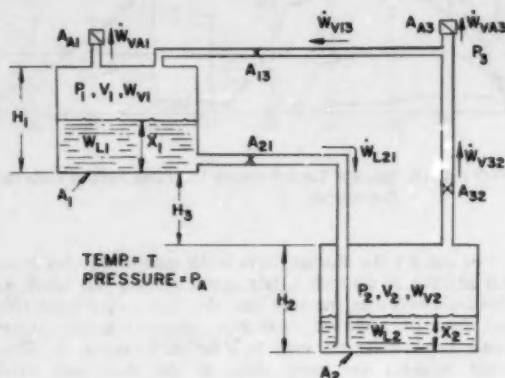


FIGURE 5: Isothermal Vapor Transfer Model.

We simulated a drop at the service stations with an isothermal vapor transfer model. I want to emphasize that the model was isothermal. But as we are finding, the temperatures tend to say that this model will be quite valid and indeed it proves to be so. We allowed for a gravity drop from the above ground tank to the underground tank. We can size our orifices in the vent return lines to approximate the hose restriction, friction, and pressure drop. AA3 would be the 2-inch vent line and/or a restrictive orifice and the vent from the underground tank. AA1 could be used to show truck leakage and its effect. With this type of model, one can very quickly trade off a vast amount of data and show in curves what to expect.

We tested our model on an isothermal drop done in Davis. We were able to get excellent correlation, assuming the truck had a

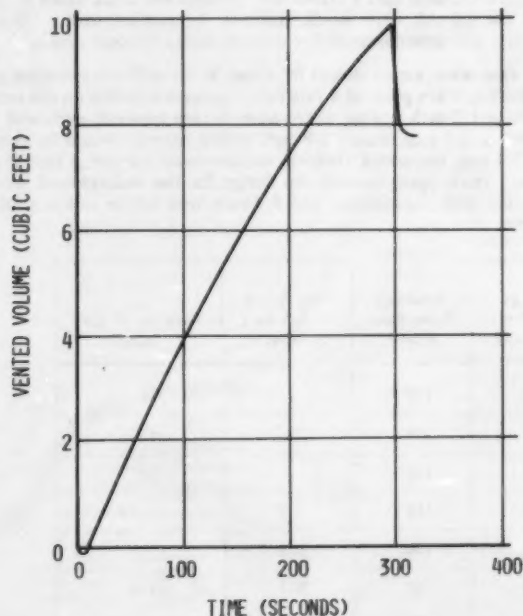


FIGURE 6: Vent Gas Volume During Storage Tank Fueling Transfer.

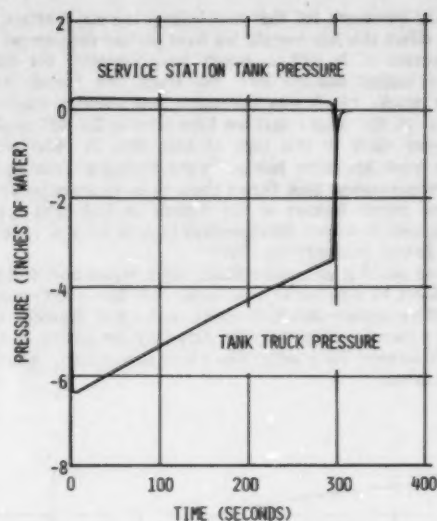


FIGURE 7: Tank Pressures During Fuel Transfer.

1/4-inch hole in it. This truck was assumed to be leak-tight. The curve dips just below zero at the start, indicating a slight inventing of air into the system. This is due to the fact that you are gaining a vacuum in your truck faster than you are building up pressure in the underground tank. Since you have a leak in the truck, you vent continuously from the system until the drop is reached. At that point, there is an ingress of air through the vent and pressure levels off. This has indeed been found to be true in actual practice.

In Figure Seven we see the pressure patterns in the above ground and underground tank in the tank truck. Let us take the underground tank first. We see that the tank builds up a small amount of pressure, maybe 3/10 inch of water. The pressure line is rather linear at that point until the drop is completed.

If we look at the tank truck, we find that a vacuum is being pulled in the truck. This test was done with a 2-inch return line of approximately six inches of water. The graph is rather linear at that point, which is the liquid head effect decreasing as the tank drains. At the end of transfer, we see that the vacuum volume in the tank truck exceeds the pressure volume in the underground tank. The ingress of air is shown by the vacuum pulled on the total system before the pressure levels out.

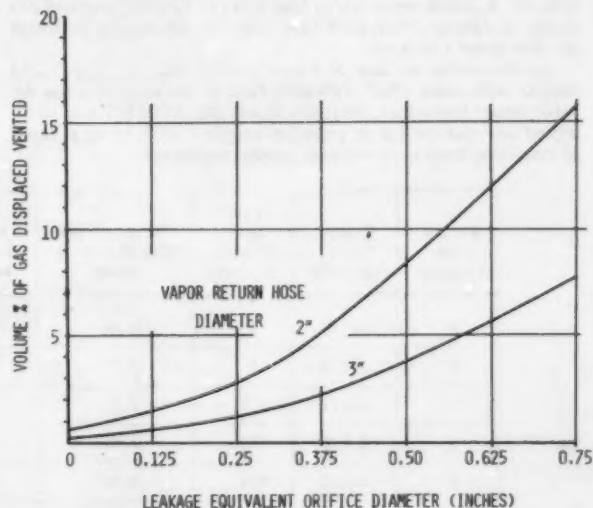


FIGURE 8: Effect of Vapor Return Hose Size On Vent Gas Volume With Truck Leakage.

We have demonstrated that tank leakage is a major effect. Let us see what effect this has overall. We have plotted the percent vented volume versus a 2- and a 3-inch hose diameter for different equivalent orifice leakage into the truck. We found that this particular truck, which was leak-tight, had about a quarter-inch hole. Most of the trucks that we have seen in the API studies are running very close to this type of hole size. In other words, a leak-tight truck has either leakage in the fittings as draining occurs into the underground tank fitting there or in tank vents. You may have some minor leakage in the system. A leak-tight system is almost impossible to get. The question is, how do you control this and how do you minimize the effect?

You can see that going to a 3-inch vapor return hose will cut the leakage effect by a factor of two. This could be a good reason why some of the programs that have shown such a high degree of leakage with vapor transfer are getting the data they are getting. They have large truck leakage. They either don't have tight trucks, or they have restricted hoses.

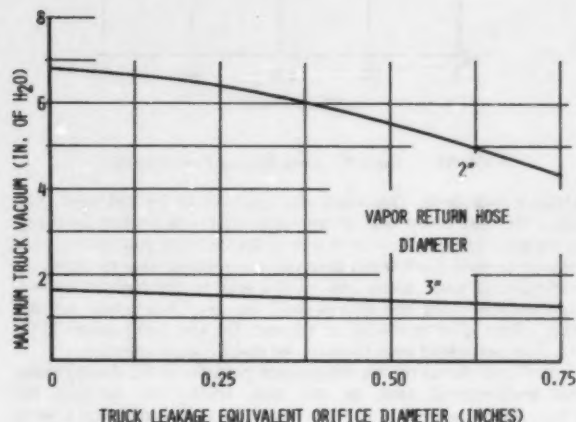


FIGURE 9: Maximum Truck Vacuum for Various Transfer Conditions.

We can see this point better when we look at the pressure patterns in the tank trucks. With the 2-inch vapor return hose, we are pulling approximately six to seven inches of water vacuum in the truck. If there is any leakage in the truck, this will suck air in, meaning that much less vapor can be displaced back to the truck later on. A 3-inch vapor return hose will run between one and two inches of vacuum. Now these have been correlated quite well with the data in our literature.

At this point, we look at Figure Ten to find out what would happen with some other trade-offs. One of the trade-offs was the vapor return line orifice. What size should the orifice be? And will it indeed do what the LA air pollution people want it to do in terms of restricting truck drops without causing problems?

Return Line (inches)	Truck Vent (inches)	Vent Line Orifice (inches)	Storage Tank Max Pressure (psig)	Average Drop Time (minutes)	Average Drop Rate (gpm)	Vent Time to 1.5 psig (minutes)	Vacuum 50 gpm (psig)
0	2-1/2	2	0.18	5.0	419	-	≈0
0	2-1/2	1	0.77	5.4	384	-	≈0
0	2-1/2	3/4	1.52	6.3	330	-	≈0
0	2-1/2	1/2	2.57	9.5	218	0.9	-0.14
0	2-1/2	3/8	3.01	14.8	138	2.1	-0.4
0	2-1/2	1/4	3.30	30.9	67	5.1	-1.8

FIGURE 11: Storage Tank Vent Line Orifice Trade-Offs.

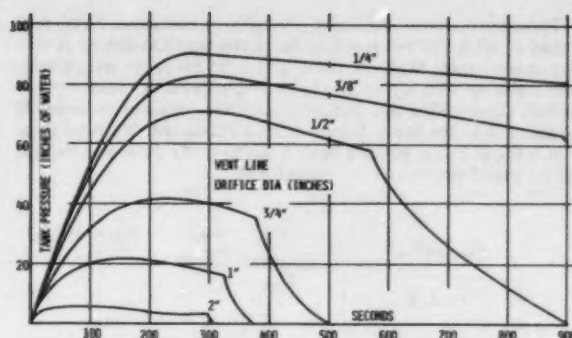


FIGURE 10: Storage Tank Pressure Vs. Time Return Line Not Connected.

You can see the bottom curve is the straight 2-inch vent orifice. With addition of a 1-inch orifice, restriction was very small. Adding a 3/4-inch orifice in the vent line also had a very small effect in truck drop times. We are, remember, trying to lengthen the time for a truck drop. When we went to a half-inch orifice, we found we almost doubled the drop time, or the drop rate would go equivalently from around 400 gpm down to around 215 gpm.

This combination accomplishes what Los Angeles wants. If we had further restricted the vent orifice to a 3/8, we would have tripled the drop time. This would have reduced the flow from roughly 400 gpm down to about 150 gpm. A quarter-inch line would have taken the flow to 16% of the drop rate, or 67 gpm.

There are some problems involved with too restrictive an orifice. First, there is a possibility of blockage. Second, the tanks are designed for a 3 psi or the equivalent of 83 inches of water. With a 3/8-inch orifice, an underground pressure is built up which just about equals the design limits on the tank. With the quarter-inch orifice, pressure exceeds design limits.

When the hose is disconnected, the operator would have to hold it up in the air to keep fuel from backing out. In other words, fuel would flow on the ground as soon as he laid the hose down. Flow would continue for approximately 50 seconds with a half-inch orifice. I assume that a 1½ psi tank pressure will cause liquid to flow on the ground. Flow would continue 2.1 minutes with a 3/8-inch orifice and approximately five minutes with a 1/4-inch orifice.

One other aspect should be noted. If the orifice is restricted and defueling takes place at a fast rate, a vacuum is pulled on the tanks. With a 1/2-inch orifice, the vacuum is very minimal, even with 50 gpm, or 0.1 psig. With a 3/8-inch orifice, vacuum would be as high as 0.4 psig, and with a 1/4-inch, vacuum could become as high as 1.8 psig, which again exceeds the design for the underground service station tank. Apparently, the 1/2-inch vent orifice makes a lot of sense.

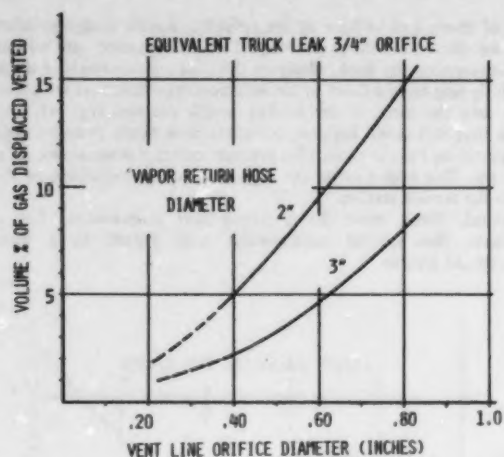


FIGURE 12: Effect of Vent Line Orifice On Returned Vapor Volume.

I was talking to Jack Weiler of Shell, who came up with a fact that really made a lot of sense. A vent orifice in addition to a large return hose size will again minimize vented volume.

In Figure Twelve we have plotted for a 3/4-inch hole in the truck. This is large leakage. A 2-inch vapor return hose with a 3/4-inch leak into the truck will vent 16% of its volume. The .833 orifice corresponds to 80 feet of 2-inch hose or 2-inch vapor line. This also gives some indication of why a 1-inch and a 3/4-inch orifice in the vent line have little effect on drop rates. There is already an approximate equivalent with 80 feet of 2-inch pipe.

With a 3-inch vapor return hose, the rates again go from 16% vented down to approximately 9% vented, providing we look at just the 2-inch open vent. If we went to a 1/2-inch vent, with the 2-inch hose, we could reduce the vented volume by 46% or from 16% total vented down to 7% vented. With a 1/2-inch orifice on a 3-inch hose we can reduce, again in isothermal conditions, down to as little as 3% vented. A 3/8-inch line could get down to 2%. Again the curve shows that only a small amount is gained by going to the 3/8-inch orifice over the 1/2-inch. Because of the other effects, we should probably leave things as they are. A question I wish to bring up later is: Does the vent line restriction represent a very effective secondary recovery device? This is something to think about.

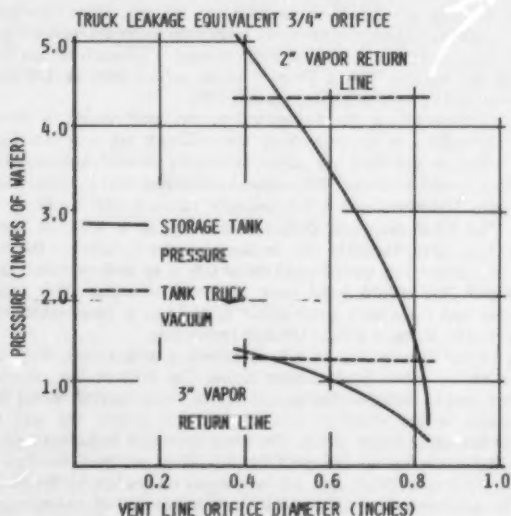


FIGURE 13: Vent Line Orifice Effect On Tank ΔP .

- VAPOR SPACE COOLING
- VAPOR COLLECTION
 1. CHARCOAL ADSORPTION
 2. VAPOR HOLDER
- VAPOR RECOVERY OR ELIMINATION
 1. CHARCOAL REGENERATION OFFSITE
 2. CHARCOAL REGENERATION ONSITE
 3. CATALYTIC OXIDATION
 4. COMPRESSION - CONDENSATION V.R. EQUIPMENT

FIGURE 14: Excess Vapor Process Schemes.

In looking at some of the pressure figures, you can see why we favor the 3-inch vapor return hose. The 3/4-inch leak provides a restrictive vent. Some appreciable pressures are built up in the underground tank, which is the upper black line. The dotted black line is the vacuum that is drawn in the tank truck. These are appreciable values both in underground tank pressure and vacuum in the truck, as shown in Figure Thirteen.

When we look at the 3-inch return hose with the restrictive vent, we see that tank truck vacuum is not appreciably affected, but we are increasing the pressure in the underground tank. Later we will look at this effect. Remember, trying displacement from an automobile while defueling a tank truck will have to be done over this underground tank pressure. If the operator is bucking only 1.3 inches or one inch of water, leakage in the car nozzle would not be so critical.

At this point, let us look at some of the excess vapor process schemes. If the efficiency shown in the previous figures is not great enough, there are certainly methods of improvement. We have looked at some of these in the equipment sections. First, we have vapor space cooling. In this area, what we are trying to do is maintain the vapor space in the tank in a non-equilibrium condition so that we can pull some air into this vapor space. Maintaining the space in this way, we can then transfer those contents at a later date to the truck. The truck then takes the saturated vapors back to the terminal.

The second method is vapor collection either by charcoal adsorption or with a vapor holder. Charcoal adsorption has certain advantages in that it tends to concentrate the vapors as it collects them. The unit can be taken off-site for regeneration. The charcoal can also be regenerated on-site or regenerated from the vapor holders. With regeneration of the charcoal, the system is again simpler because the vapors are concentrated. Methods used to accomplish this regeneration or recovery include catalytic oxidation as well as some others which I have chosen to lump together as compression-condensation VR equipment, which in many cases is a miniaturization of terminal equipment.

If we had to go cost-wise, we would certainly say that charcoal regeneration off-site is the least expensive from a capital cost standpoint. In fact, I believe Calgon officials said that they have installed the canister for nothing. I am not sure about the cost for piping. Charcoal regeneration on-site and catalytic oxidation would be second in cost. The VR type equipment would be more expensive still, perhaps doubling the cost of the first two methods.

Figure Fifteen demonstrates losses from service station tank breathing. Two losses occur in this area. First, we find diurnal losses which are due to temperature and pressure variations in the underground tank because of ambient changes. Second is the vapor loss due to saturation of inbreathed air. This occurs when all the car refueling vapors are not displaced back to the underground tank. Air is then sucked in at the tank. This causes some evaporation of fuel

1. DIURNAL LOSSES

2. VAPOR LOSS DUE TO SATURATION OF INBREATHED AIR

FIGURE 15: Service Station Tank Breathing.

and some vapor loss at the vent. If there is no vapor return from the automobile as the underground tank is defueled, more air is sucked in, and this air will cause evaporation and further vapor loss.

The question is, how big are the losses? With displacement, they are probably very small. Some new work that is just now coming out indicates that the diurnal losses are quite small. This is because evaporation rates are less than we had previously thought. Too, the vent line volume is the appreciable of the total volume vented in and out. When talking about in-breathed air, we feel that secondary recovery is almost a necessity.

• EMISSION CONTROL APPROACHES

1. VAPOR TRANSFER TO SERVICE STATION TANK
2. ONBOARD CARBON CANNISTER APPROACH

• PROBLEM AREAS

1. TANK REFUELING NOZZLE INTERFACE
2. TANKS WITH EXTERNAL VENTS
3. AUTOS WITH EMISSION CONTROLS

FIGURE 16: Automobile Refueling Losses.

Let us look now at the automobile refueling loss. As we have just stated, there are two basic emission control approaches. First, we can use vapor transfer to the service station tank or to a carbon canister. I assume the vapors would go primarily to the underground tank because vapor displacement with vacuum assist is the more prevalent method. Second, we could use the onboard canister approach. Olson Laboratories showed that the onboard canister approach is viable with about three times the present amount of carbon.

There are three problem areas involved. The first concerns the tank refueling nozzle interface, which we have discussed at length. The second problem concerns tanks with external vents, or pre-1970 automobiles. As they try to displace the vapors from these cars, operators lose some through these vents, or air is sucked in through the vents into the tank, perhaps creating a hazard. Finally there are the autos with emission controls. Too much vapor vented through these emission control canisters causes losses. With the onboard canister approach, automobiles will have to be retrofitted. With the vapor displacement approach, considerations must be made for the external vents, emission controls, and so forth. We will be looking at

1. MUST BE ABLE TO VENT LIQUID AT REFUELING RATE WITHOUT OVERPRESSURIZING TANK
2. MUST BE VAPOR-TIGHT CONNECTION

FIGURE 17: Refueling Nozzle Design Problems.

a few of these. Let us look at the refueling nozzle design problem. First, we must be able to vent liquid at the refueling rate without over-pressurizing the tank. Many of the types of nozzles that we are now designing have a boot or an inflation type structure which will wedge into the tank. If the fueling nozzle did not shut off, and I believe that this could happen, complete tank pump pressure might be imposed on the car tank. This pressure could, I understand, go up to 25 psi. This might cause the explosion or the expulsion of that tank in the service station.

Second, there must be a vapor-tight connection. Let us investigate this second requirement with regard to a direct displacement system.

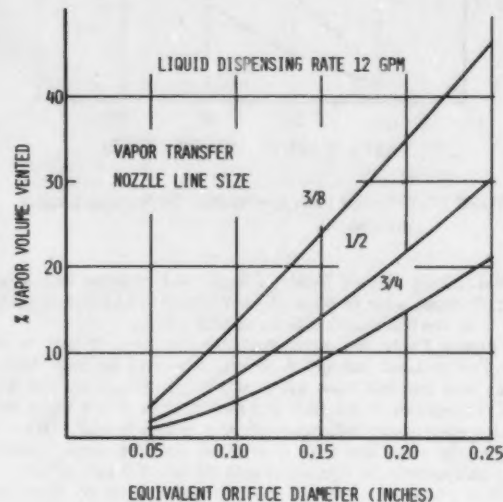


FIGURE 18: Volume % Vented As A Function of Nozzle Leakage.

In Figure Eighteen we use the same vapor transfer model that we had before, so we must consider this as strictly an isothermal situation. What is primarily shown here is some kind of tradeoff that will indicate what kinds of nozzle line sizes are necessary and what types of pressures are developing.

If the nozzle has a 3/8-inch vapor return line, the maximum orifice size as far as leakage and leakage at the nozzle are concerned would be only around 70-thousandths of an inch. Since cars with vapor canisters have approximately a fifty-thousandths-inch orifice, a leak-tight nozzle is needed if there is only a 3/8-inch return line around the nozzle. With a 2 1/2-inch vapor return line, an 1/8-inch orifice would be needed before venting 10%.

If we were to use the 3/4-inch line, the result would be about 160-thousandths of an inch. With the 3/4-inch vapor return line, then, chances are that on most externally vented automobiles, recovery would be about 90% without restricting that external vent.

Figure Nineteen shows the pressure patterns that build up in tank. The 50-thousandths orifice builds up, in a 3/8-inch vapor return line, approximately two inches of water pressure in the car tank. A 1/2-inch line would build about 0.6 of an inch of water, and a 3/4-inch line would build only .03 inch of water. This again indicates that there isn't much affect of leakage. A reasonable hole size would be all right with a 3/4-inch return line.

In Figure Twenty we see vehicle refueling with a tank drop, all controlled by vapor displacement alone. The bottom line, from a previous graph, indicates the percentage of vapor vented versus the equivalent orifice diameter with a 3/4-inch return line and no vehicle defueling taking place. The same operation including vehicle defueling is shown on the next line up. Here we used 80 feet of 2-inch pipe, no orifices, and a 3-inch vapor return line to the truck.

The difference here is caused by a slight amount of underground tank pressure, 0.3 inches of water. This is enough to cause restriction and a higher pressure drop in the vapor displacement line back to the underground tank from the vehicle. There is no increase

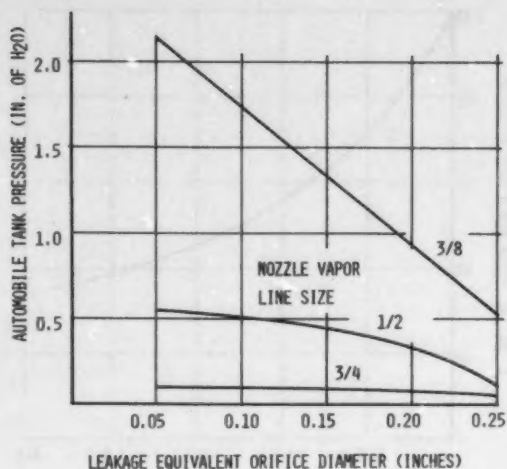


FIGURE 19: Automobile Tank Pressure.

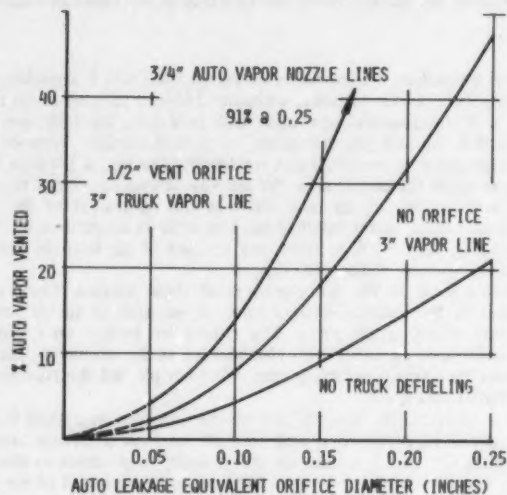


FIGURE 20: Vapor Displacement From Auto During Tank Truck Defueling.

in pressure to the outside, where leakage would occur. The difference in pressure drops makes a smaller orifice necessary. In other words, there cannot be as much leakage before venting the 10% volume.

With a 1/2-inch vent restriction, a 1.3 inch underground tank pressure is build up rather than a 0.3 inch. This further restricts the effect of pressure drop in that area and causes the leakage problem to become ever more critical. The results are similar to those of the 3/8-inch nozzle to about a 70- or 80-thousandths equivalent hole. This graph certainly points out the fact that a virtually leak-tight nozzle is necessary with vapor displacement alone. Let's take a look at one approach to that problem.

Let's consider for the moment a fueling adaptor to be carried by the motorist. The male end would mate leak-tight with the automobile, similar in operation to the fuel cap. The female end would mate leak-tight to the fueling nozzle. The fueling nozzle would have a male end, which would mate leak-tight to the fueling adaptor. A relief valve would be included and/or sufficient vent line size to prevent tank overpressures.

The problem with this approach is twofold. First, car legislation is preempted from local jurisdiction. The local people have the problem of solving the smog, but they don't have the power to

- FUELING ADAPTER CARRIED BY MOTORIST
 1. MALE END MATES LEAK-TIGHT WITH AUTOMOBILE
 2. FEMALE END MATES LEAK-TIGHT WITH FUELING NOZZLE
- FUELING NOZZLE
 1. MALE END MATES WITH FUELING ADAPTER
 2. RELIEF VALVE AND/OR SUFFICIENT VENT LINE SIZE TO PREVENT TANK OVERPRESSURES
- PROBLEM
 1. CAR LEGISLATION PREEMPTED FROM LOCAL JURISDICTION
 2. NOZZLE ADAPTER INTERFACE MUST BE STANDARD

FIGURE 21: Leaktight Nozzle Approach.

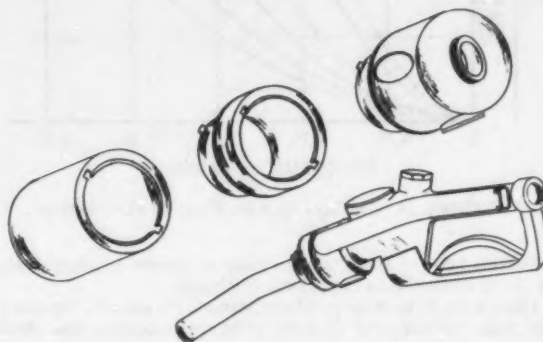


FIGURE 22.

require retrofit on automobiles. Second, the nozzle adaptor interface must be standard. If the connection is not standard, then a different adaptor will be needed for every community in which a car is refueled. Standardization is a must.

Figure Twenty-two shows what one of these devices might look like. We have here the tank, a simple type adaptor, and a screw-in type adaptor that can be adapted to the present nozzles. The system would have a vent relief valve, making the filling station attendant responsible for proper functioning. The system would probably have a 3/4-inch vapor return line. There might have to be several different adaptations for different automobiles because of various restrictions in the area of the fill pipe.

Let us examine some of the present nozzle approaches. First, some companies use a magnetic seal at the car. Second, some companies use the sponge rubber pressure type seal in which the bellows actually supplies the pressure. Third, there is available an

- SEALING CONCEPTS
 1. MAGNETIC SEAL AT CAR
 2. SPONGE RUBBER PRESSURE SEAL
 3. EXPANDABLE BOOT
 4. EXPANDABLE DIAPHRAGM
- PROBLEMS
 1. LEAKAGE
 2. EMERGENCY RELIEF VENTING
 3. LEAKAGE WHEN UNCONNECTED

FIGURE 23: Present Nozzle Approaches.

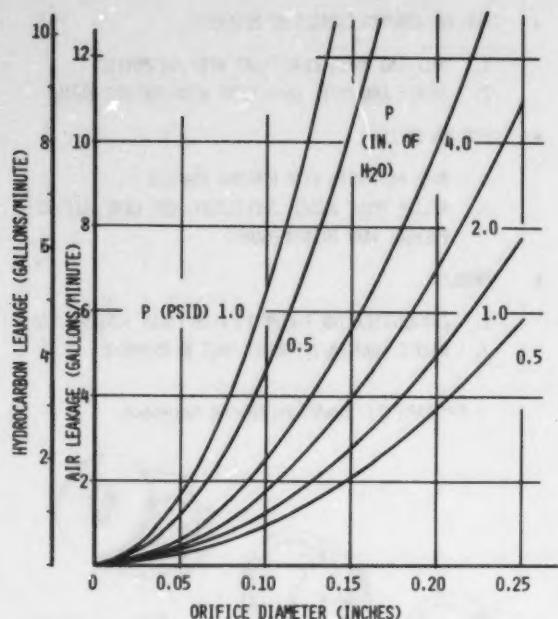


FIGURE 24: Gas Flow Rate Vs. P and Orifice Diameter.

expandable boot of some kind to cause expansion at a boot area. The fourth method is an expandable diaphragm.

There seem to be three problems, leakage, the second emergency relief valve venting, and leakage when unconnected. The third problem can be solved by an interlock valve in the vapor line or by a simple check valve. The occasion of emergency relief venting is something which needs more serious consideration. At a 12-gpm refueling rate with a 1 3/8-inch nozzle of some type, a pressure of one psi is built up in the tank. This pressure will vent through that opening, which is about equivalent to 3/4-inch. We do have a vent problem, and if we restrict that opening any more we may end up with a venting problem from the vehicle fuel tank.

Figure Twenty-four is a montage of working curves. These can be used to calculate leakage rates into and out of a vehicle tank

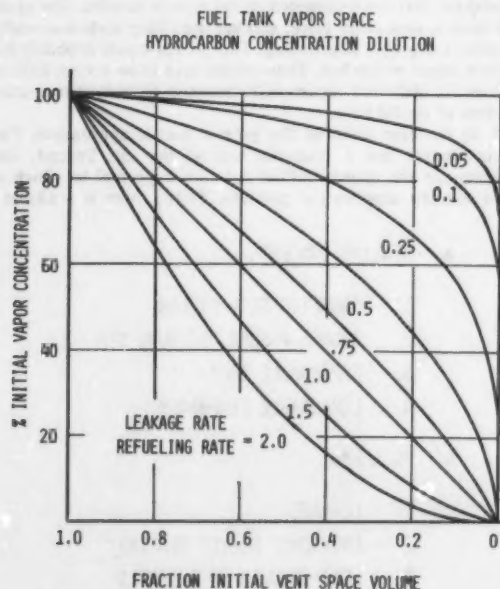


FIGURE 25: Fuel Tank Vapor Space Hydrocarbon Concentration Dilution.

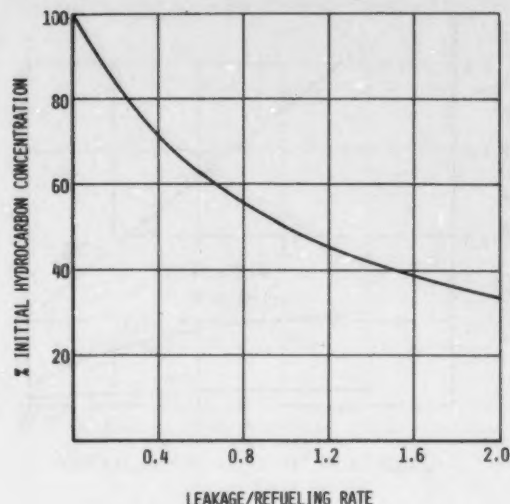


FIGURE 26: Return Vapor Dilution Due to Air Leaks at Nozzle.

versus equivalent orifice diameter versus the Delta P available as a driving force. If, for instance, we have a 1/2-inch vacuum in the tank and a 25-thousandths equivalent leak hole into the tank, we can bring into the tank approximately six gpm of gasoline. Some of the external vents on pre-1970 cars are actually this big. A 1/4-inch leak is nothing in the nozzle area. We are now talking of nozzles that do not seal at all. In this case, there is the equivalent of the full 3/4-inch orifice, and possibly more. Under those conditions, we may be pulling three to four times the amount of air into the system than the amount of displaced vapors.

Let's look at the consequences of these actions. First, with respect to the automobile fuel tank, as we suck in air we have a dilution effect taking place. The curves can be run on a sort of dimensional pattern if you plot leakage as the parameter, that is, leakage rate versus refueling rate. We have plotted the fraction of the initial vent space.

In other words, how far are we through refueling when 0.2 of the initial vapor space is still left? If we have a leakage rate to refueling rate of 0.5, we can see that in order to get down to about a 30% vapor concentration we would have to be almost all of the way through the refueling of the vehicle. This condition seems to be somewhere near the limit. In pre-1970 cars with large leakage holes, we might get a hazardous condition or a flammable condition in the fuel tank, although this would not normally be experienced.

Figure Twenty-six shows the effect in the nozzle area. We are using a 1-over-a-plus-x type plot. To get down to a 30% dilution factor—or a 30% dilution of the initial hydrocarbon concentration—would again require a leak of more than twice as much air as hydrocarbon vapor being displaced back to the system. With some of the vacuum concepts shown, this certainly is true. With those systems having a tight fit or in which the nozzle does touch the interface, the system is relatively leak-tight, and there should not be any vacuum problem in the nozzle area.

I would like to bring up four points in summary. First, we have shown that a vent line orifice markedly improves efficiency over the straight vent line. Second, a leak-tight nozzle approach is possible and very necessary. Third, we have somewhat quantified the conditions under which a hazard exists in both the fuel tank and the return fueling line. Finally, we are using vacuum-assist at the service station and pulling in three times the air that we normally would. If we saturate this air prior to going back to the underground tank and if indeed we have 90% recovery of the four volumes of air that are returning, we would then have a 60% overall recovery. The 1/2-inch vent orifice provides 50% recovery. A 3/8-inch vent orifice provides 74% recovery. When looking at a vacuum-assist, we must always trade off the efficiency of the recovery device we are putting on versus the degradation in performance that we are creating by sucking in the added vapors. Thank you.

DISCUSSION PERIOD

MR. SCOTT: At this point I would like to ask the chairmen to assemble up on the podium. We will spend as much time as we can answering those tough questions which have worked up. I think our objective now should be to wrestle with the major questions that have been raised.

I would like to take the chairman's prerogative, if I may, and respond to one question which has been raised both from the podium and in the corridors. That question is: Why don't the petroleum industry and the hardware industry get together and solve these problems without any horsing around?

The question bothered me last night, and so this morning I made contact with one of the major anti-trust legal firms in Los Angeles. Here is a very brief statement dictated to me over the phone this morning: "The oil industry has, in many instances, considered collective action among its members or in conjunction with other industries to solve a particular problem. Legal counsel has always advised against such action when instances of collaboration have resulted in legal action by the Justice Department, Federal Trade Commission, other governmental bodies, and private interests for improper restraint of trade. The Justice Department has made it abundantly clear that it will continue to vigorously enforce the anti-trust laws." I hope that this response turns off some of the apparently unwarranted criticism that has been tossed around.

MR. BRATTAIN: I would like to make a comment. I think that reply is a typical legal reply. I would like to point out to you gentlemen that a lawyer has a built-in reason for advising you not to do something. If you don't do it, you can't get in trouble. The only time that a lawyer can be proved wrong is when he tells you to go ahead. Then he gets caught off base. I think that you make a tactical error in ever asking an attorney whether you should do something. The proper way to use an attorney is to tell him what you are going to do and then ask him how to do it and stay out of jail.

MR. SCOTT: Okay. I think we should open the discussion to questions now.

MR. JOHN PERRY: Vaporex. I would like to direct a question to Dr. Nichols. Could you slowly go through the rationale with regard to conducting an isothermal model for all of your work? I didn't understand that aspect, and I think it is important.

MR. NICHOLS: I am not ducking the question in any way. I will be very frank with you. The order of magnitude of work going into a non-isothermal model is infinitely more than that going into an isothermal model. We are presently doing this work in considering heat transfer effects. Just to give you some order of magnitude, the equations jump from approximately 16 in number to probably over 40. The calculation just becomes a very, very difficult job.

We have looked at what the variation is with temperature, and the curves we have shown do seem to give the effect at one particular temperature—any particular temperature. You could extrapolate from that the extra vapor growth you would achieve if you had a Delta T in either direction. These are, therefore, good working curves for one particular point. Our program and problem, however, are much more difficult. The program is being achieved, but it will take a little bit longer.

The question is, "Would I modify my conclusions under such a circumstance?" Possibly the non-isothermal transfers in a service station and the non-isothermal transfers at the vehicle would provide a much larger effect than would leakage or return hose size. This has not proved to be experimentally true. Neither have the temperature data showed such an effect. What has been found is that the temperatures of the fuels are predominantly in such a position as to cause a negative, rather than a positive vapor growth.

MR. BILL PETERSON: Esso Research and Engineering Company. Looking through some of these curves which relate to vent line size on the pre-71 or pre-70 vehicles, I see that an occasional vehicle having greater than a 1/4-inch diameter hole would have a high percentage of vapor vented during a straight displacement. If I look at dilution curves, however, I find that if this vehicle with the large diameter hole were to come in and we were to try to collect the excess vapor being vented, we would need pressure which created an explosive mixture. I draw the conclusion that we have got a choice between collecting excess vapor from a small percentage of cars with a larger than normal vent hole or putting explosive limits in a small percentage of cars. If there were one out of a thousand cars that was giving us a problem, we would have a choice of losing 1/10 of a percent of vapors or blowing up 1/10 of a percent of the cars.

MR. NICHOLS: We have indeed thought about this matter. Cars with a large external vent, if the operator were using a pressure displacement, would lose a reasonable portion. Perhaps 30 to 40% of the vapor would be vented externally. Bill has pointed out that this is the same situation you presently have in a service station. On the other hand, he is pointing out that if you suck in that much air, you create a hazard in the fuel tank. This hazard may indeed be a much worse problem caused by the vacuum-assist than the vapor venting caused by pressure displacement. This was the argument given by Vaporex.

MR. CLIFF SOUSA: With Phillips, a friend of the FTC and the Justice Department. Mr. Brattain, I would like to make a comment to you concerning the laws of our land. There was a joint publication by the energy producers in this country and the Department of Interior called *An Energy and Ecological Outlook for Our Country*. In the foreword, these parties requested exemption from anti-trust laws. Such exemption was denied.

MR. SCOTT: I would like to ask another question, one that seems left unresolved from this morning. If the gentleman from Underwriters is here, I think this question should be addressed to him. I think we understood this morning that Underwriters' approval probably was required for OSHA regulations on new nozzles, but I certainly didn't understand whether or not such approval was required for adaptors that would be used with existing nozzles in order to meet the regulations. Is the gentleman from Underwriters here to respond to that?

VOICE: Well, I certainly can't speak for OSHA or any of the other government agencies. We can only go by what they have published in the *Federal Register*. But if at any time OSHA or any of the other government regulation agencies call for a listed product, they will be calling for a product of which we have knowledge.

When you talk about adaptors, you bring up a question that someone asked me since this morning. What is Underwriters' position on a product that has been modified after it leaves the factory? Does this modification actually void the listing? Does the product require supervision or listing by others? As far as I know, if Underwriters does not have supervision of the modification, it cannot say that it is still the same product we listed. We already have programs to check over the modifications and insure that the product, as changed, does not break any of the requirements that originally applied to the product when we listed it. We also have programs in which we can recognize the changed product as varying from some of the initial requirements.

MR. SCOTT: Does anybody else have any questions regarding such approval before we leave this issue? What about other questions?

MR. CURTIS CORTELYOU: Mobil Oil Corporation. I have sat through this seminar and heard the term "cost-benefit" used a great deal. I suspect that if I were not familiar with the subject, I might have gotten the impression that technology was available, or nearly so, and cost benefits were favorable to control vapor losses such as those we have discussed here today and yesterday. I am thinking of the thousands of dollars of cost that even the vapor balance system, without any secondary recovery, is likely to represent to a single station. I am also aware, as Don Walters mentioned, of the job required not only to protect the environment in a lot of different ways, sulphur oxides and others included, but also simply to provide the energy that we need to provide. This is itself a big job.

Without diminishing in any sense the importance, benefit, or need to have this technology available, I suggest we need to keep in perspective—very carefully—the multitude of subjects. We must not conclude that because saving hydrocarbon vapors here helps the energy picture and is in the right direction, we should pursue that area to the exclusion of all else. Thank you.

MR. BRATTAIN: Mr. Chairman, I would like to comment on this. I happen to agree with the way you concluded, Mr. Cortelyou, but I would like to point out that the people who discussed this subject did not say anything about cost-benefit. They said something about cost-effectiveness. The two terms have different meanings. Cost-effectiveness is a calculation of cost for effort. Cost-benefit includes a comparison of the amount of money you spend with the benefit derived from that expenditure. The subject cost-benefit was not discussed by any speaker I heard at this symposium.

MR. HOWARD KLEIN: Standard Oil. I am also on the EF-14 Task Force for API. I would like to point out that the electrical energy required to collect this excess vapor is also requiring fuel. We should look into this very carefully, because we have reason to

believe that we might be consuming three times as much fuel in producing electricity as in salvaging one gallon of gasoline.

MR. HARVEY GRIMES: Atlantic Richfield. I have a similar point, perhaps a little more broadly stated. I believe it touches on the discrepancy in positions that seems evident this morning in terms of effectiveness of vapor balance and the data supporting that conclusion. I would like to point out that there has been as much progress as would be expected over a period of time with the direct displacement system. We can do a better job today than we could a year ago or even six months ago. So perhaps some of the earlier data, the high excesses, do not reflect the latest in primary recovery technology.

We have fueled cars in a direct displacement test as they came off the road at a commercial service station, over 100 cars in several days' time. While not covering seasons or all geographical areas, we can say that our results, combined with the truck drop deliveries and vapor balance systems, indicate that we captured over 90% of the total vapor that would have been emitted in the non-controlled situation. So we view cost-effectiveness with considerable skepticism concerning that last 10% increment on the average. We are quite certain that the true figure would represent many, many dollars per gallon of material recovered for that last increment.

MR. BRATTAIN: I think what we heard today indicates that if the 90% figure is really correct, then the cost-effectiveness becomes questionable. I think, however, that there was a definite discrepancy in the data. I believe your data are very definitely subject to the proposition that somebody was there supervising. I mean you were taking observations, and you were fueling cars off the road. But you were still fueling those cars in a test situation. This seems to me all the more reason for some standardization of test methods. We could then be certain that your 90% figure is correct.

Finally, I don't think all the figures should be lumped together. I think we should talk about recovering 70 or 80 or 90% of the vapor that is lost in refueling the car and leave out the underground tank figures. Any combining constitutes a dilution of the data, which tends to cloud any discrepancy. As everybody has pointed out, this type of control should be on a regional basis, specifically in areas where it is needed. The program should not be nationwide, and consequently I think we have to discuss cost-effectiveness in terms of a particular locality. I don't think there is any reason to feel that data, just because they were taken on one location, are not valid. They are good for that location. We will have to collect information in several different types of climatic conditions and several different localities before we can apply it to more than one basin.

MR. SCOTT: Bob, may I ask you a question? You brought up the point of standardization of test procedures. Certainly we have seen a basic difference of philosophy between APCD's. Is the proper role of the regulatory agencies—for example, CARB—to establish standard test procedures that could be used?

MR. BRATTAIN: I would suppose so. We were, of course, hoping that a standard test would come out of either the API or possibly this SAE panel. Now, of course, the difficulty with any standard procedure is that you can standardize it only if the particular pieces of equipment are put in a tent.

When data are gathered from people driving into a service station in which you have equipment, it is extremely difficult to have an overall standard procedure. We have to be very careful that we are talking the same language.

Mr. Gockle calculated that the cost-effectiveness of displacement was much better than that of a secondary recovery. He found that secondary recovery could get another 20% of the hydrocarbons, at a good cost-effective ratio, but not so good as displacement. His figures, however, may not be correct when we consider any recovery over 90%.

VOICE: If we spend several thousands of dollars for a secondary recovery unit, we still can't count on the cost-effectiveness of the truck delivery portion of the vapors being the same as the lower percentage for the vehicle refueling. That is the reason, when you talk cost-effectiveness, for looking at each total. We, of course, do look at the figures separately.

Let me clarify one point. I did not say that, on the average, we obtain 90% recovery on vehicle refueling. 80 to 85% is a better figure, and we think that can be improved. We are continuing our tests.

DR. NICHOLS: Yes. Up to now we have considered that the

theoretical calculations that I presented are totally independent of reality. Let me assure you that if you take Mike Liefberman's report and look up the pressures in the tank trucks and the underground tanks and plot the data on the curves, you come up with almost identical percentage recoveries. There is a good correlation.

Let me make another point. If you plot some of Mike's data against Standard Oil's standard refueling transfer where the nozzle was held very tightly, you can find that where the observers could get engagement of the nozzle, they had quite good recoveries involving vapor displacement with the present nozzles. These things do match quite closely with the theoretical predicted curves. We have, therefore, a good basis of knowledge to work from, as a predictive approach to what can be achieved. And this, I think, has a tremendous amount of merit for establishing laws and analyzing trade-off data. If you can predict under what conditions you are going to have bad recovery, you can predict under what conditions you will have acceptable recovery. This is very definitely a part of our program at Parker. I think that theoretical work is being done in industry as well, even though the test procedure isn't totally standardized. I think we are coming to the point where we can be predictive in our vapor displacements. I don't think we have quite reached that point, but I think our technology is very rapidly developing in that direction. The Standard Oil data, the ARCO data, and the data of the various agencies are all independent at this point. Correlation of all these results is only just now becoming available. The results do show a very good correlation with theory, and I think we can be predictive of this efficiency level I mentioned.

MR. WILLIAM PETERSON: Esso Research. I would like to comment on two questions. The first concerns the standardization of any test procedure. What I understand of the test procedure, and I may be quite wrong, is that it is a takeoff on the Scott Shed system, which enclosed the vehicle and then refueled it. If you examine that system, the only real information derived is how good your seal is on the vehicle and how much material gets out of the vent line. The Scott Shed system certainly does not answer the question of what happens to the vapor after it goes through the balance displacement system. If my understanding of the standardized test procedure is correct, then that system is not applicable to this question at all.

In any current case, I think when we look at experimental data we should examine the experiments run on the merit of that particular program and not against what some agency has decided would be the best for everyone. Different programs have different needs in terms of the type of data that a person is trying to collect. Let's be scientists and look at things on their own merit. When we present data, we must explain to people how we got those data. I think that is lacking. We should not expect standard data. I do think we should give all observers the chance to set their programs up as they will.

I had one other point, with regard to the temperature effects on refueling. It is my understanding that hydrocarbon standards are set to be derivative upon oxidant standards. If we are going to look at times of the year when talking about climatic conditions with the most potential for vapor growth, whether or not such growth exceeds acceptable limits, those periods would probably occur during the winter months, which are certainly beyond the photochemical smog period.

MR. BRATTAIN: No, I am sorry, your last comment is not correct. There have been high oxidant standards found in Denver during very cold weather.

MR. PETERSON: Again, there are different localities to look at.

MR. BRATTAIN: You implication that winter automatically means freedom from photochemical reaction is not correct, sir.

MR. JIM KELLER: From Union Oil. Several times we have mentioned the need for a standard, effective test procedure to measure how well a system works on the auto fuel spout. How effective will we be if we compare different systems on the same basis?

CRC-APRAC had been in the process of setting up a program to develop such a test procedure, not just a laboratory shed but a real procedure that could be taken out to a service station and used to evaluate the effectiveness of recovery systems. Unfortunately, one of the three supports of such programs had to drop out of it, namely, the Motor Vehicle Manufacturers Association. The petroleum industry and EPA were the remaining two. For policy reasons, EPA had to withdraw from these CRC programs as well. That program, just about to go, fell on its face, and we don't have any procedure being developed now.

MR. BRATTAIN: I agree with Dr. Nichols' position that we should get a theoretical model which, even though it is restricted to particular conditions, might produce data to agree with experimental data taken under similar conditions. In so doing, we may find our way around the rather difficult problem of a standard test method. We could probably then use the theoretical models to point out which way we ought to be going.

MR. SOTHERS: API. I would hope that somehow we can leave this seminar with some guidance as to what we might expect in the way of further activity, aside from the general education which I think we all received. I hope that somehow the sponsors of the conference will attempt a follow-up very shortly on these various areas, such as standardization of fill pipes and nozzles, so as to help advance this whole effort. We should try to find a way to get these things rolling rather than wonder why somebody else isn't doing so. Perhaps if we talk to each other, soon, while all of this discussion is fresh in our minds, we will find a way.

MR. ROY VAN WINKLE: Dresser Industries, Dallas. May I address a question to Dr. Nichols? A number of us have sat through the conference listening with interest to what was said. I find one question constantly recurring. It concerns these recovery percentages. Could you, in layman's language, tell me how you determine what 100-per cent recovery is, so we may know how the 90 or 75 percentage was arrived at?

MR. NICHOLS: Quite simply, we are talking volume percentages in most cases. If we consider that the volume of fuel pumped into a tank generates so much vapor, we ask what percentage of that vapor goes back into the dispensing tank. If 10% of that amount is lost, then you have a 90% efficiency. Now you can have either a decrease or an increase in the amount of gas that comes off a tank compared with the amount you put in. This is because of temperature effects and condensation which may occur due to fuel and gas interaction. When we speak of 90% efficiency, then, we are talking of the volume coming off the tank. A 90% recovery means 90% of that gas volume is transferred back into the receiving vessel or that 90% of the hydrocarbons from that volume of gas are recovered.

The subject becomes a little more complicated when we begin to talk about air-vapor mixtures that are unsaturated and about test procedures on equipment. Basically, most equipment is tested on the basis of a saturated inlet vapor condition. You are again talking about a 90% removal based on a saturated inlet vapor condition. This is, of course, just the nature of your recovery equipment.

MR. RON JACKSON: State of Arizona. I'd like to say that we do not, at this time, require any kind of vapor control at the service station level either for vehicle refueling or fuel dumping. I think in the future, however, we will have such a requirement. I think we are going to have a lot of capable footsteps to follow in when we do.

Motorcycles, gasoline cans, and various containers of this type are typically filled to a level very near the fill spout. This practice would not allow the fuel nozzle to be extended into the tank. I was wondering if this type of filling would be sufficient to constitute a significant problem. If so, has anybody actually done any thinking in that area?

MR. SCOTT: Doesn't one of the petroleum companies know what percentage of gasoline is sold to motorcycles?

MR. WALTERS: All I know is that there was a ban, or partial ban, on motorcycles in the transportation plans. These have not been modified, because the logic behind putting them in originally, as I recall, was that the emissions grams per mile are very high for a 2-stroke engine. Emissions are several times as high as those of late model cars. While we don't want to ignore an uncontrolled emission source, a motorcycle is something that people can use in place of cars. But then the motorcycle people asked us to set some emission standards for them, so they could still continue with motorcycles. I don't know if there is an analogy there you could possibly pick up.

MR. BRATTAIN: Motorcycles are high emitters. There is a program in California now to determine what the emissions levels are. That program does not necessarily include what percentage of gasoline is sold to motorcycles. Even though motorcycles are high emitters in grams per mile, they get many miles per gallon. Really a very small fraction of the total vapor loss may be accounted for by filling motorcycles.

MR. JACKSON: I was thinking not only of motorcycles, but also of gas cans for people who have motor boats and lawnmowers.

MR. BRATTAIN: Yes, but I think that percentage is even smaller.

MR. JACKSON: With the gasoline shortage, we may see a lot more 5-gallon cans being filled. Then there really will be a problem.

MR. LUNCHE: I would guess that most motorcycle tanks have less than a 5-gallon capacity. The legislation that I have seen drafted, or that is already on the books has a cut-off point at five gallons. If you fill a can that holds less than five gallons, these controls would not be required.

MR. JACK TODD: Dresser Industries. I have a comment regarding the questions on motorcycles, cost-effectiveness, and the answer that you just gave Mr. Lunche. I am wondering whether the conflicting percentage figures for effectiveness of the vapor displacement system might be concluded to be more than 90% under ideal conditions, and less than that under other conditions.

If seasonal temperatures change the effectiveness of a vapor displacement system, how will that fact be considered in the overall picture? If, for instance, a vapor displacement system effects over 90% recovery for most of the year, with something less than 90% during the three winter months, will you average the total recovery for the year?

MR. LUNCHE: A yearly average is not what we are looking for in Los Angeles County. I know there is an opinion that certain emissions can be averaged. We have never believed in this averaging. We say 90% recovery every time.

MR. DONALD WALTERS: Every time you test?

MR. LUNCHE: Our standard probably boils down to what Don just asked. We mean we want 90% vapor recovery every time a vehicle tank or an underground tank is filled.

MR. RAY EDWARDS: Edwards Engineering. I would like to address my question to Dr. Nichols. Your charts show that during the time you are filling the underground tanks at the service station, you are going to be raising the pressure in the tanks. At the same time, then, you will have difficulty with collecting gasoline vapors at the automobile. There is a perfect example of a condition in which you can't collect vapors every time, because the pressure may go up to two or three inches during that period. Conversely, if you are going to use a negative pressure to collect gasoline vapors at the automobile, you probably do not want to use the 2- or 3-inch negative pressure because of the possibility of sweeping considerable amounts of air into the vapor. What we are really saying, then, is that during the time you are filling the underground tanks, you are not going to do much vapor recovery by displacement methods.

DR. NICHOLS: I think that is why I went to the large hose size recommendation on the nozzle, the 3/4-inch and the 3-inch return hose. Under those conditions, you can indeed get very close to 90% recovery by vapor displacement, but that large a percentage will require the nozzle to make a tight seal on a canister type car with a typical 50-thousandths orifice. Under other conditions, where you have a larger external vent, you definitely would not be able to. That is why I believe you need the larger vapor lines under all circumstances. That also means another problem. If you have a 3/4-inch vapor line, you cannot put a 3/4-inch solenoid valve in the line to turn flow on and off. The CV of the solenoid valve is probably equivalent to a 3/8-inch orifice and consequently ruins everything else in the line. These are some of the things that must be taken into account.

MR. GORDON POTTER: Exxon out of Houston. I would like to explore a little further this idea of percentage recovery relative to time with Mr. Lunche. I can appreciate the fact that an average throughout the year with this system might prove to be excessive. We wouldn't help ourselves much in the summertime if we averaged out the winter. I believe the purpose of capturing vapors is to prevent air pollution. Now, is not air pollution essentially a diurnal phenomenon? When you develop a smog situation, isn't that situation due to action of the sun and temperature on hydrocarbons captured in the air by some type of meteorological phenomena per primary substance? That smog is really the result of an accumulation of hydrocarbons since the onset of those particular conditions.

A logical answer might be to have a 24-hour average. If the amounts of hydrocarbons put into the air over a 24-hour period are kept to that limit, we would have, I think, a far more logical control than if we tried to hold everyone to a single measure. We know from the beginning that some can't meet the other standard anyway, because of the connection.

MR. LUNCHE: We have problems of enforcement, Mr. Gordon. To say that some can emit less than the average and some can emit more would place an impossible burden on any enforcement agency.

I think we have to draw the line somewhere and say "This is the minimum." If you are worried about an average, you had better design for an average that is above the set minimum.

MR. POTTER: In view of Mr. Nichols' proposal that this average could be predictable on a theoretical basis, wouldn't that approach lead to the same end? We could then determine, by the equipment and the method of vapor handling, that over a 24-hour period we would in fact recover more than 90% of the vapors. We know full well that on occasion we would not make it. That is one approach to regulation enforcement. We could predict our average control ahead of time, rather than by testing each vehicle.

MR. LUNCHE: I don't think we can operate an enforcement program that way.

MR. WALTERS: I think that system implies a 24-hour test method. The tax payers would go broke paying for it. A one- or two-hour test on these things costs enough in most cases.

DR. NICHOLS: There is also a question of practicality involved. In vapor displacement, if you have holes or leakage spots in your system, the method is not effective. Consequently, there is a maintenance problem. I think the single point test is almost necessary. You must shut the poor-maintenance facility down until you make certain its equipment is good. This is mandatory if you are going to allow a vapor displacement only test.

We can assure people that if a truck has less than a 3/4-inch orifice we will get 90% recovery. But how do we insure that? We can insure that by direct field tests, which are rather stringent tests for a vehicle truck. Testing means you have to straighten all your dome covers and have all your relief valves working. Furthermore, these tests will require a rather good test maintenance procedure for trucks. But, you will not find the cost prohibitive if you go to the effort of making large-diameter lines. I think you would have to test vehicles at random to make the law meaningful.

MR. JIM MASTEN: Las Vegas, Nevada, Air Pollution Control Engineer. I have sat through this whole thing, and I don't feel yet that I have gotten an adequate definition of cost-effectiveness, not one that I can understand in dollars and cents at any rate.

MR. BRATTAIN: Cost-effectiveness is the amount of money you spend to remove a pound of some particular pollutant or prohibit the emission of a pound of a particular pollutant to the air. When you say that vapor recovery is more cost-effective than controls on a new car, you are comparing the cost of the controls on a new car to the amount of money you would have to spend to get service station control of vapor emissions down to an equivalent level.

The EPA paper showed that you get about 10 pounds of hydrocarbons per dollar of expenditure. This was in Mr. Winkler's paper. The test of the canister in the API project that was being run by Olson Laboratories showed about 7½ pounds per dollar. After you have the device on the majority of the cars, the cost goes down to 13¢ a pound. This is about 7½ pounds per dollar. Now, if you spend a dollar on some other method, such as our NOX retrofit devices, you get only two pounds of retroactive material out of the air instead of 10 pounds. We say then that the retrofit device is only 1/5 as cost effective.

MR. GOCKEL: While we are on the subject of cost-effectiveness, I would like to point out that there are lots of assumptions one must make in the numbers that I presented today. My figures were for the average service station, and I used an average of a 35,000 gallons of fuel per month per station. I think before we make the decision of whether or not the whole industry should go to a displacement system only or to some secondary system, we should consider there might be a cut. In other words, vapor recovery systems at the bulk plants are very cost-effective. There are some very high volume stations on freeways, for example, that pump well over 100,000 gallons per month. We may find out that in that instance, there would be some cut point of maybe 75 to 150,000 gallons. I am not sure how this will finally come out, but I just want to make that point.

MR. BRIAN GIBBONS: Husky Oil out of Denver. Would high elevations or extreme winter temperatures have any adverse effects on the conclusions that you people have made here, with regard to your sizing of any of the equipment?

DR. NICHOLS: Your question certainly has some implications regarding that vent line orifice which I don't have any answers for. I have explored with several people the problems of what to do in the winter time with cone-roof tanks that have flame arresters and vent valves in them. Will you explode tanks by leaving in the vent valves and the flame arresters? Do they indeed freeze up or not? I believe

that industry practice is to remove the flame arrester during the winter. Some companies even remove the vent valve platters to avoid the freezing problem.

Now we come to the question of practicality, and this is an area which I think has to be investigated further. In this regard, vapor recovery becomes more difficult and, in other ways, easier. At the very low temperatures, you tend to have less vapors. If you are trying to recover the same percentage year round, recovery becomes more difficult at cold temperatures. At high altitudes, the percentage of hydrocarbons in the total amount coming back as vapor is higher, which fact makes recovery easier in some respects. Condensation type equipment or low temperature equipment in general must go to a much lower temperature during the winter season. That makes the process more difficult. So you have to look at the individual case, and I would think that we have found in terminal equipment that there is a great deal of adjustment necessary for climatic conditions. I think this would also be true of other types of equipment.

MR. BOB LIMMER: J. E. DeWitt, Incorporated. I want to know what we are going to do with this vapor from the pump islands. Do we put the vapor back in a tank? Which tank do we put it in? Can we vent the vapors into the 3-inch vent pipe? What is the regulation on that?

DR. NICHOLS: I don't think that we have given much thought to that particular problem, but I don't see any reason why there could not be manifolding so that vapors could go to any tank.

MR. LIMMER: Can that vapor be vented into the 3-inch vapor line also used for transfer back to the truck?

MR. LUNCHE: Offhand, I don't see anything wrong with that idea, but again we haven't examined it.

DR. NICHOLS: There is one problem. To keep from digging up the station, some people have proposed putting the vent connection over on the riser, some 110 to 120 feet away from the truck. When I talk of an equivalent 3-inch hose, I mean an equivalent 3-inch hose 20 feet long, not a 3-inch hose 150 feet long. If you do run a very, very long hose, then you should have a hose with a greater diameter, and that presents problems. When we are speaking of vapor displacement, we are talking direct vapor displacement in most cases. Two or three years ago, we thought that a 50-foot hose 1½ inches in diameter would recover the truck vapors and that we could hook it onto the vent line. I think that the aspects of a practical vapor recovery displacement system makes this impossible. If you are speaking of a vacuum-assist and so forth, my opinion might be different.

MR. LIMMER: I am considering the 3-inch vent line that is going back to the truck for the recovery. I mean the 3-inch pipe coming up the riser and venting at the island into the lower part, right next to the fill.

MR. NICHOLS: To my knowledge, no air pollution division of any jurisdictional location has told anybody how to design his piping. This does not include, of course, any regulations pertaining to product contamination and so forth. Where you put the piping is up to you. I don't think anybody has tried to dictate piping to the individual user.

MR. JOHN CARROLL CAGNEY: EPA Region I. How does the panel feel about where we ought to go from here in the regulatory aspects? What do you think of the 1975 deadlines for Phase 1 and 1976 for Phase 2 in light of some of the comments made at this conference? I think we might have some disagreement across the panel, and I am wondering how far apart the members actually are.

MR. SCOTT: Would you care to poll the panel.

MR. CAGNEY: Yes, essentially.

MR. WALTERS: As I understand the EPA position now, and I speak from semi-ignorance, our technical people were forced to make some decisions. They have come up with this Stage 1 and Stage 2, and have picked some dates. I am sure these deadlines are pushing the technology, at least that has been my experience in the past. My further impression is that not everyone involved will be able to meet these deadlines. As for the vehicle end of our program, I didn't hear anybody say he was going to make it, and I didn't hear anybody say he wasn't.

MR. BRATTAIN: Your Stage 1 does not include vehicles, does it? That is involved with the underground tanks. The earliest date was the 1975 date?

MR. WALTERS: March of 1976.

MR. BRATTAIN: March of 1976 is the earliest date.

MR. DICK PENNA: EPA. The earliest compliance date for Stage 1 is in two air quality control regions in Texas. I think the date is

May 31, 1975. All other places that require Stage 1 have either a March 1975 or a May 1976 deadline. Stage 2, which involves the filling of vehicular tanks, has a compliance date of, I think, May 31, 1977. Whether we will make it or not is something that we are going to find out.

MR. BRATTAIN: I don't think that I have heard anything at this seminar which would justify, at the present time, changing those dates. Now, after all of the information is assimilated and people have a chance to take a second look at it, there may be some necessity for change. These may even be justification for moving some compliance dates ahead a little. But I think that it would be a mistake to say, on the basis of what we have just heard, that the schedule should be delayed. We have over two years, in most cases, for the underground tanks and over three years for vehicle fueling. As one of the gentlemen who spoke for ARCO pointed out, even in the past six months the displacement systems have improved significantly. If we continue to get similar improvement in the next couple of years, then those are quite reasonable compliance dates.

MR. SCOTT: Are there any wind-up comments?

MR. RAY EDWARDS: Edwards Engineering. Another gentleman was asking about what to do with the recovery material, where you could drop it back into the ground tank. We have done considerable work on our own plant on direct condensation of the vapors at minus 100 degrees. This is done by a very simple process, so obviously we have collected a tremendous number of samples.

The material collected is water white, of very low viscosity, probably on the order of centapoise. You can hold the liquid in your hand, or put your hand around a test tube full of it. We have actually seen it literally explode and disappear during a hot summer day. There is no tetraethyl lead in the liquid that we can see. There is no dye, either. It is absolutely water white. We haven't had this residue analyzed as to the exact hydrocarbon content, but probably it is mostly isobutane, butane, and whatever else you would expect to get in this type of operation.

I don't think the tank you are going to put the liquid back in is very critical. From a 100,000 gallon per month station, you would get about 170 gallons of this residue coming back, which is not a very large quantity.

MR. MEL LECKENFELDER: Mobil Oil Corporation. I would like to go back to the EPA for one second, if we may. I would like some clarification on the requirements of these regulations that were promulgated in the November 6, 7, and 8 *Federal Registers*. We are talking here about dates that go into 1976 and 1977 for Phase 1 and Phase 2, but I think there are some interim dates which come as early as 1974 and which require the filing of certain compliances with plans. Am I correct or not?

Considering some of the discrepancies we have heard here this afternoon, particularly regarding the collection of vapors from the automobile tank and pump interface, how can we file a compliance plan within the next six months when we are really not sure how the technology will come about? Will the interim date be waived in some cases, or what do we do?

MR. WALTERS: I don't know. I am not familiar enough with the details, so I will call on Mr. Penna again.

MR. PENNA: One of the reasons I came out here was to determine whether the dates that we have in the plan are realistic.

One of the things that I intend to do when we get back to Washington is sit down and start talking about this problem with people who are in the policy decision-making position.

MR. SCOTT: For those of you who may not be familiar with this, the paragraph reads "June 1, 1974, negotiate and sign all necessary contracts for emission control systems or issue orders for the purchase of component parts to accomplish the emission control." I think in view of the information divulged at this seminar, compliance obviously is going to be impossible.

VOICE: Isn't it also a fact, from the dates of November 6, 7, and 8 in the *Federal Register*, that by law, you either have to file a suit or forever hold your peace or depend on the good sense of EPA to come to the conclusions that are being assumed by us? In other words, after December what happens?

MR. PENNA: The Act provides a 30-day period in which anyone may file a petition for review. In most cases, at least in California and Texas I know, most of the major oil companies have filed such petitions. In other states I am not sure what is happening. In most places, just from a practical legal sense, I think people would be foolish not to file a petition for review.

MR. BRATTAIN: I was going to ask you that question.

MR. PENNA: The Act does say you must file petitions for review within 30 days or else waive your rights.

MR. WALTERS: That is the case unless your petition for review is based on some new information that has developed subsequent to approval of that plan.

MR. PENNA: Right. That or any sort of constitutional grounds will give you an extension. You can bring up these arguments at any point.

MR. WALTERS: Essentially every one was challenged on some of the other implementation plans in the district courts around the country. I would suspect that all of these transportation plans will be challenged, too. We have done rather well in the other cases.

CLOSING REMARKS

by

Carleton F. Scott

I think on that cheerful note we will close this meeting. In summary, we have seen that a great deal of progress has been made. I think that now we also see some major problems associated with safety, compliance dates, and particularly in conflicts with our federal regulations.

We owe a real debt of gratitude to the sponsors of this meeting, the participants, the audience certainly, and particularly to the very hard working chairmen who put this thing together. I remind you of the quasi-divine guidance which the California Air Resources Board received last night. I quoted this message earlier, but I think it is good enough to be quoted again, particularly in light of the last comment. "Be true and trust each other, and all will be well."

We are adjourned.

APPENDIX

CONTROL OF REFUELING EMISSIONS WITH AN ACTIVATED CARBON CANISTER ON THE VEHICLE

by

Donel R. Olson
John A. Gunderson
D. K. Lawrence

INTRODUCTION

The automobile has long been recognized as one of the major contributors air to pollution. Since the 1960s, various standards have been imposed by state and federal agencies to limit vehicle crankcase and exhaust emissions. Beginning in 1970, controls for vehicle evaporative emissions were initiated. A remaining source of vehicle emissions is that which occurs during refueling when hydrocarbon vapors are displaced from the vehicle fuel tank.

OBJECTIVE

The primary objective of this project was to determine the technical and economic feasibility of using a carbon canister system on automobiles to control refueling vapor losses. A secondary objective was to ascertain the effects of this system on vehicle exhaust emissions, evaporative emissions and driveability.

TECHNICAL APPROACH

To initiate the design of a prototype carbon canister system capable of handling refueling vapor losses, studies were undertaken on a bench-test system to define the total amount of refueling vapor to be handled, vapor retention capacity of activated carbon, and purge capacity over a range of refueling conditions and fuel system parameters.

The system was fabricated, installed on a test vehicle and evaluated under simulated use conditions. Measurements of refueling emission control, effect on exhaust emissions and effect on driveability were then conducted to allow modification of the system design and ultimately to permit determination of effectiveness. Manufacturing cost estimates were made and cost effectiveness was calculated.

PROJECT PARAMETERS

Three refueling conditions were considered in developing the emissions recovery system. Qualitatively, these conditions have been identified as nominal, severe and extreme. Factors that help to quantify these conditions are listed in Table 1.

TEST FUELS

As defined above, the refueling conditions and estimated vapor losses are predicated on climatic conditions and fuel characteristics. To provide the necessary test fuels, a blend of a 9.1 psi RVP, unleaded regular grade with another commercial fuel having a 12.1 psi RVP was used to essentially match fuels identified in Table 1 for nominal and severe conditions.

Table 2 provides the inspection data for the three test fuels.

The Indolene 30 test fuel was used to conduct the vehicle exhaust emission tests in accordance with federal test procedures.

No weathered fuel was used for testing purposes. As the fuel was required, samples were drawn in quantities sufficient to conduct

scheduled tests. Fuel inspection tests were conducted to assure uniformity. Unused samples were disposed of if not consumed during testing operations.

Table 1. REFUELING CONDITIONS

Description	Test Condition		
	Nominal A	Severe B	Extreme C
1. RVP, psi	9.0	10.5	11.5
2. Fuel dispensed, gals	17.0	18.0	22.0
3. Tank fuel temp., °F	95.0	95.0	112.0
4. Dispensed fuel temp., °F	82.0	82.0	82.0
5. Calculated HC vapor emission, grams/gal.	5.6	6.4	9.0
6. Calculated HC vapor recoverable (grams)	95.0	115.0	198.0

Table 2. TEST FUEL INSPECTION DATA

Characteristics	Fuel		
	A	B ¹	C ¹
Fuel Description	Indolene 30	46% 54% X Y	10% 90% X Y
RVP, psi	9.2	10.8	11.5
ASTM Distillation, °F			
10%	133	118	114
50%	223	206	206
90%	321	308	314
Lead, g/gal	3 (Nom.)	0.66 ²	1.10 ²

1. Blend of fuels X & Y as shown.

2. Computed from concentrations in blending stocks X & Y.

The test fuel was transferred to a fuel conditioner where the temperature could be controlled and flow rate to the vehicle fuel tank or experimental tank could be regulated.

TEST VEHICLE

A new 1973 Ford Gran Torino with a 351-cubic inch engine and a two-venturi carburetor, automatic transmission, air conditioning, power steering and power brakes was used in this project. This vehicle was selected as being representative of a popular model passenger car.

As compared with other popular models of Chevrolet and Plymouth, Ford vents the carburetor internally, using a relatively smaller carbon canister as part of the existing evaporative emission control system and purges the canister into the air cleaner instead of the intake manifold. These features of the Ford system permit relatively simple modifications using existing commercially available components. The fuel filler neck on the Ford is also readily accessible, permitting ease of modification to evaluate various methods of achieving fuel nozzle sealing.

CONTROL SYSTEM DESIGN CONSIDERATIONS

Figure 1 shows a diagram of the evaporative emission control system as currently in use on the 1973 Ford 351 CID engine. The design objective was to retain as much of the current configuration as feasible to facilitate the modification toward a combined evaporative-refueling emissions control system.

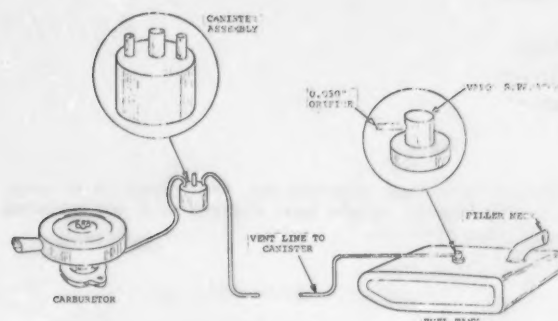


FIGURE 1: Existing Evaporative Emission Control 1973 Ford Gran Torino

Theoretical data, assuming saturated conditions were used to estimate the amount of vapor that would be generated during refueling under the refueling conditions previously defined.

Figure 2 shows the relationship between fuel RVP, temperature,

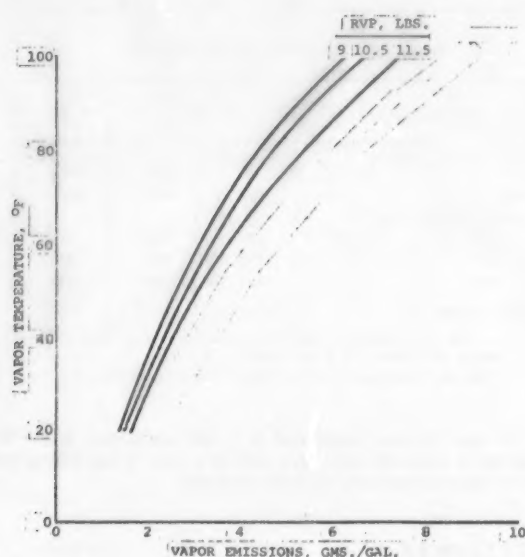


FIGURE 2: Influence of RVP and Temperature on Vapor Emissions During Refueling

and vapors generated. For the extreme condition of 22 gallons refueling and HC vapors emanating at a rate of 9 grams per gallon (see Table 1), the capacity desired is 198 grams. Thus, the carbon canister used to store the vapors must be sized to allow storing 198 grams of refueling emissions plus that normally stored for evaporative emissions occurring during hot soaks and diurnal losses.

Table 3 shows the results of bench testing the preliminary configuration. Results for the nominal and severe conditions were in good agreement with predicted results. For the extreme condition, however, results were substantially lower than the theoretical

Table 3. BENCH TEST RESULTS

Characteristics	Refueling Conditions		
	Nominal	Severe	Extreme
RVP	9.2	10.8	11.5
Fuel dispensed, gal	17.0	18.0	22.0
Tank fuel temp., °F	95.0	95.0	112.0
Dispensed fuel temp., °F	82.0	82.0	82.0
HC vapor to canister, gm	86.6	97.4	51.4
HC vapor, gr/gal dispensed calculated average	5.1	5.4	2.9

prediction. A prototype canister with 2000 grams of carbon was fabricated for some preliminary bench tests prior to vehicle testing. The objective was to initially charge the virgin carbon in the prototype canister prior to running a seven mode-seven cycle exhaust emission test on the vehicle. Additionally, testing was designed to provide some indication of actual canister working capacity by charging and purging several times while monitoring the weight of the canister. A sketch of each of the bench test setups is shown in Figures 3 and 4.

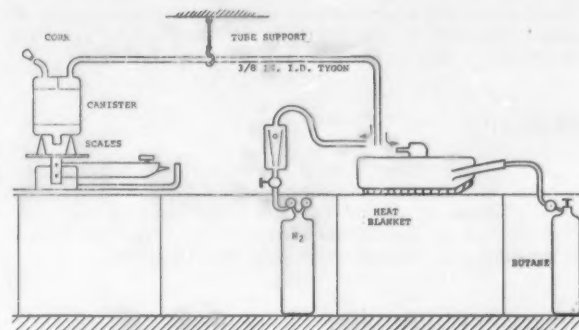


FIGURE 3: Canister Charge and Purge Bench Testing

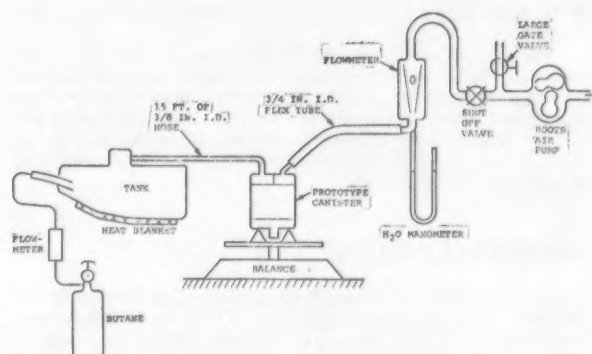


FIGURE 4: Arrangement for Charging and Purging Prototype Canister

Based on various bench tests coupled with actual vehicle testing, the prototype system included the following changes to the evaporative system of the 1973 Ford Gran Torino test vehicle.

System Element	Present Evaporative System	Prototype Combined System
Carbon Canister	700 grams	2000 grams
Vapor Separator Spout	0.050\" orifice	0.375\" I.D.
Transfer Tube to Canister	0.25\" orifice	0.375\" I.D.

An elastomer diaphragm placed in the fuel tank fill pipe provided a tight seal between the fill pipe and refueling dispenser nozzle. Bench testing indicated a positive seal against vapor escaping up the filler neck. However, these prototype seals were subject to tearing and deterioration. The proposed version of the seal is shown in Figure 5.

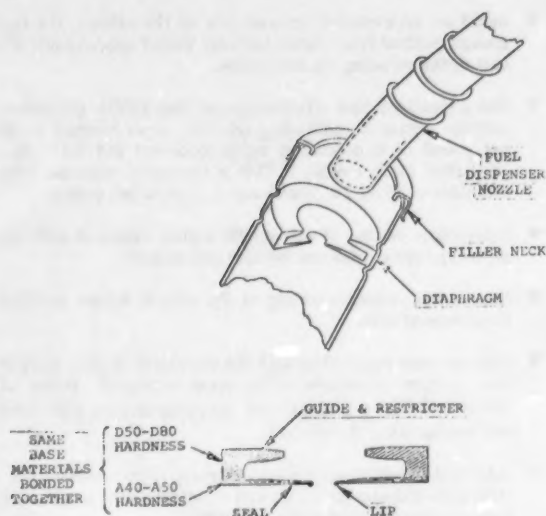


FIGURE 5: Proposed Seal Material: Vinyl-Nitrile Compounds (Cross Section: Full Scale)

The test vehicle exhaust emissions were measured both with and without the prototype canister control system that was installed following the 1975 CVS mass measurement procedure. Composite averaged results for six tests are shown below.

Statistical analysis of exhaust emission data indicated that the change in HC was not significant. The increase in CO and the decrease in NO_x were both significant with a 95 percent level of confidence.

	Exhaust Emissions (g/m)			Evaporative HC (grams/test)
	HC	CO	NO _x	
Production System	3.26	40.66	3.67	0
Prototype System	3.44	51.67	3.08	0
	+0.18	+10.81	-0.59	

Effects of the prototype system on vehicle driveability were determined using the test procedures developed by the State of California Air Resources Board. The results showed that vehicle performance was not degraded when the prototype system was installed.

The effectiveness of the program to recover refueling vapor losses is dependent on the yearly introduction of new controlled vehicles, the attrition and salvage of older uncontrolled vehicles, and the relative amount of fuel consumed by the controlled and uncontrolled vehicles. Assuming implementation beginning with 1975 models, the following table shows the degree of control for selected years.

Control	Calendar Year		
	1975	1979	1984
Vehicles Controlled (Percent)	8.1	47.2	84.2
Fuel Dispensed Under Controlled Conditions (Percent)	11.9	58.0	91.7

COST ANALYSIS

A detailed cost analysis model was developed to provide a framework for computing and evaluating the unit production cost and the total program cost associated with each feasible design. Estimates were made for the effects of inflation on labor, material, and gasoline cost. The cost model also included the necessary factors to determine the annualized cost.

The unit cost, in 1975 dollars, will increase above the existing evaporative control system cost by the following amount:

	Control System for		
	Nominal	Severe	Extreme
Carbon Canister, Grams	1780	2000	1060
Unit Production Cost	\$2.65	\$3.09	\$2.00
Unit Consumer Cost	4.48	4.85	3.13

COST EFFECTIVENESS ANALYSIS

Two cost effectiveness (CE) indices were used. One CE index was based on the yearly effectiveness estimate of HC vapor recovery and the corresponding cost incurred yielding a ratio of dollars spent per pound of HC recovered. The other CE index was based on the amount of vehicle fuel dispensed and the costs incurred to control refueling vapor emissions providing a ratio of cents per gallon.

The total program consumer costs, with and without fuel savings considered, were annualized as were the cost effectiveness indices shown below:

\$ per pound (without fuel savings) 0.18
¢ per gallon (without fuel savings) 0.10

Data in Table 4 provide other pertinent summary information and are presented in a different format to allow total program visibility as a function of implementation year. While annualized indices provide a simple method for comparative purposes, they lack program perspective and need to be supported with other substantive information.

Table 4. SUMMARY OF CHARACTERISTICS (Severe Refueling Conditions)

Characteristics	Calendar Year		
	1975	1979	1984
1. <u>Passenger Vehicles</u>			
Quantity Controlled (10 ⁶)	7.3	48.6	103.6
Proportion Controlled (%)	8.1	47.2	84.2
2. <u>Refueling Vapor Recovery</u>			
Equiv. Wt. (10 ⁶ lb)	83.8	464.3	875.0
Equiv. Vol. (10 ⁶ gal)	15.5	86.0	162.0
3. <u>Fuel Dispensed to</u>			
Controlled Pass. Veh. (10 ⁹ gal)	7.0	39.0	73.6
All Pass. Veh. (10 ⁹ gal)	58.6	67.1	80.1
4. <u>Incremental Cost Difference^a</u>			
Manufacturing (10 ⁶ \$)	36.8	48.4	69.6
Consumer (10 ⁶ \$)	57.8	76.0	109.3
Vapor Recovery Savings (10 ⁶ \$)	5.4	31.4	63.5
5. <u>Annualized Cost (10⁶\$)^b</u>	48.54	48.54	48.54
6. <u>CE Indices, Consumer Costs^c</u>			
\$ per lb. vapor recovered	0.69	0.16	0.13
¢ per gal. fuel refilled	0.83	0.19	0.14
7. <u>CE Indices, (Costs less Fuel Savings)^d</u>			
\$ per lb. vapor recovered	0.62	0.10	0.05
¢ per gal. fuel refilled	0.75	0.11	0.06

Notes:

^aYearly costs are escalated, non-discounted, base year 1975.

^bAnnualized manufacturing costs are escalated, discounted to 1975 dollars, with capital recovery rate of 10 percent.

^cConsumer costs are manufacturing costs marked up 1.57.

^dConsumer costs are credited by amount proportional to fuel savings.

For example, consider the individual vehicle manufactured during the study period of 1975 through 1984. Each succeeding model-year vehicle's cost effectiveness becomes less attractive compared with the previous model year because of the anticipated increase in the cost to manufacture and install the system in relation to the relatively unchanging amount of refueling vapors recovered. However, for the total control program involving the cumulative total of vehicles-in-use equipped with the recovery systems, quite the converse is noted. Program cost effectiveness increases with each succeeding year because of the increasing proportion of controlled vehicles-in-use and the relatively uniform annual costs. Annualized indices do not provide this type of program evaluation. The reader is thus cautioned on his interpretation and use of all reported data.

GENERAL CONCLUSIONS

Testing and analyses of a prototype carbon canister are the basis for the following conclusions:

- A canister containing 2000 grams of activated carbon, approximately three times as large as a 1973 Ford production canister, effectively controlled refueling vapor losses and evaporative emissions.
- Refueling vapor losses during severe conditions were determined to be 5.4 grams per gallon of fuel refilled, on the average.
- Assuming the refueling control system were installed on new light-duty passenger vehicles only, beginning in 1975, then 47 percent of passenger vehicles would be controlled at the end

of five years (1979) and 84 percent at the end of ten years (1984).

- The differential cost to the consumer for adding the refueling control capability to an existing evaporative control system has been estimated to be \$4.85 per manufactured vehicle. This is about one-half of that estimated in the Refinery Management Services (RMS) study for the API.
- Based on an expected ten-year life of the vehicle, the fuel savings realized from vapor recovery would approximate the cost of the refueling control system.
- The annualized cost effectiveness of the 2000-gram carbon canister system in controlling refueling vapor losses is \$0.18 per pound of hydrocarbon vapor recovered and 0.10 cents per gallon of fuel refilled. This is compared with the RMS estimates of \$0.41 per pound and 0.22 cents per gallon.
- Driveability testing of the sample vehicle equipped with the prototype system did not indicate impairment.
- Evaporative emission testing of the sample vehicle revealed no adverse effects.
- Exhaust emission testing with the prototype system showed that carbon monoxide (CO) level increased, oxides of nitrogen (NO_x) decreased, and the hydrocarbons (HC) level was not significantly affected.
- Additional developmental work is necessary to minimize the effects on exhaust emissions and to integrate the evaporative and refueling emission control systems.

CONTROL OF REFUELING EMISSIONS STATEMENT BY GENERAL MOTORS CORPORATION

by
Stuart W. Martens

ABSTRACT

This document considers the question of controlling automobile refueling emissions for the State of California. Control of those emissions either onboard the vehicle or within the service station, are discussed. In either case, a modification of the fuel dispensing nozzle is required. The nature of refueling emissions strongly suggests a regional control approach, via service station hardware. Available service station control hardware appears applicable to all vehicles in a population, whereas onboard control is practical only for new car installations. Consequently, the service station approach would provide the most rapid control possible where clearly demonstrated need exists without unnecessarily penalizing other regions of the state.

INTRODUCTION

In Los Angeles, hydrocarbon emissions from most of the steps of gasoline transfer in the distribution chain have been regulated for some time. The final step in that distribution chain—installation of the fuel into the using vehicles—has not yet been controlled.

A regulation for control of this refueling emission mode has been established in San Diego, but has not yet been implemented.

A relatively extensive research program recently completed confirmed many previous estimates of the magnitude of vehicle refueling emissions as about 5 g/gal. of gasoline dispensed. This emission level was translated into an approximate g/mi rate of almost 0.4, nearly identical to the originally established 1975-76 Federal exhaust hydrocarbon standard of 0.41 g/mi. Intensified interest in the possibilities of controlling the refueling emission mode is, therefore, understandable.

Since photochemical smog in Los Angeles results largely from hydrocarbon emissions, it is reasonable and proper that the State of California should assume leadership in pursuing control of refueling hydrocarbon emissions. History has demonstrated, however, that air pollution control decisions made by the State of California have national implications. Consequently, we believe that this entire question should be considered in the broad sense of the national interest.

Uniqueness of the severe photochemical smog problem in Los Angeles has been recognized in Federal legislation through exemption of the State of California from Federal pre-emption of new car emission control. The essentially regional nature of automotive air pollution has recently been recognized more explicitly by the report of the RECAT committee.¹ The RECAT committee pointed out that a substantial fraction of the nation does not require the severity of automotive exhaust emission controls legislated for 1975-76 by the 1970 Clean Air Act Amendments. They consequently proposed a two-car strategy which would allow sale and use of cars controlled only to the 1970-71 level in many areas of the nation.

The uniqueness of hydrocarbons in the spectrum of air pollutants makes it particularly important that variable regional need for pollution control be considered in the question of refueling emission regulation. In the absence of a general statewide (or nationwide) need for refueling emission control, it should not be imposed statewide—unless such control is free of any significant disadvantage. On the question of possible advantage not pollution related, the amount of fuel loss previously attributed to this emission mode amounts to slightly more than 1/10 of 1% of the fuel used. On the question of disadvantages, it is demonstrated in the following discussion that control of refueling emissions involves substantial added complication and cost whether the bulk of control equipment is installed on individual vehicles or in the service stations. It is consequently felt that a major consideration in selection of the point of control for refueling emissions—vehicle or

service station—should be the ease with which control can be imposed on a localized or regionalized basis.

PRINCIPLES OF CONTROL

Refueling emissions are an inevitable result of the displacement of vapor when liquid fuel is added to a partially full tank. Accidental liquid spillage adds to displaced vapor loss although the total magnitude of such spillage has been shown to be relatively minor.¹ All of the control methods which have been suggested for refueling emissions fall into one of four categories:

1. Capture and disposal of the lost hydrocarbons at the time of fill, e.g., incineration within the station or the vehicle.
2. Capture and storage of the lost hydrocarbons for disposal at a later time—either at the station or onboard the vehicle.
3. Condensation of vapors by cooling for return to either vehicle or service station supply tank.
4. Elimination of the tank vapor space through use of a collapsible tank—implies use of a submerged fill dry-break dispenser.

CONTROL AT THE SERVICE STATION

Review of Suggested Methods

The most frequently suggested method for service station control of vehicle refueling emissions involves a device on the dispenser nozzle which affects a vapor-tight seal of the interface between the nozzle and the vehicle tank filler pipe. Plumbing would be provided in this sealing device for routing the displaced air/vapor mixture back to the service station for disposal.

Disposal could be accomplished through immediate incineration by catalytic or direct flame burner. The displaced gases alternatively may be returned to the service station's storage tank, either to the vapor space (a volume of gases equal to the liquid withdrawn must be inducted into the tank to maintain a constant pressure) or to the liquid for at least partial condensation. Another suggestion for vapor disposal involves the storage of the emitted vapors on activated charcoal for later, more convenient ultimate disposal²—to the service station fuel storage tank, an incineration device or removal from the service station premises.

With the existence in Los Angeles of control for other transfer losses in the distribution chain, the obvious extension of that control to the final vehicle refueling point is frequently suggested.⁴ More specifically, the concept of merely passing displaced vapors back to the prior storage tank is visualized as a simple solution to ultimate transfer of all such losses back to the refinery. There remains in this approach, the problem of vapor disposal at the final transfer point—the refinery. Further, the mechanics of the approach are complicated by the existence of substantial temperature differences between some steps in the transfer chain.

A second general category of service station control methods involves a nozzle device which imposes a loosely-controlled clearance at the vehicle filler pipe interface—with connecting vapor plumbing imposing a pressure depression on this clearance. This concept has been described as the vacuum cleaner approach. Disposal of the vapors thus "vacuumed" from the fill interface can be handled by the same methods described above for the sealed interface system.

Finally, the vapors being emitted from the tank could theoretically be condensed by a cooling medium for return either to the service station or the vehicle storage tank. Necessary cooling could be provided by mechanical refrigeration with the cooling heat exchanger either applied at the dispensing nozzle or remotely in the service station together with one of the vapor removal plumbing approaches previously described. In addition to the obvious complexity and expense of such a system, necessary subcooling of the recovered condensate would impose additional burdens on the tank breathing loss control system—whether the cooled liquid was returned to the vehicle or to the service station.

Since, in general, the dispensed liquid fuel comes from an underground tank at a significantly lower temperature than the vapor contained in the vehicle tank, the possibility of condensing refueling vapors by the supplied liquid fuel is intriguing. Appendix A describes an investigation conducted by General Motors of the potential for such a control technique. It is shown by this investigation that normal underground storage temperatures are not low enough to condense a substantial fraction of the refueling emissions. Auxiliary subcooling of the service station fuel supply, however, might improve that situation significantly.

Important Practical Considerations

All of the described service station control methods involve additional hardware on the fuel dispenser nozzle which alter its interface with the filler pipe. Because of the variety of filler pipe geometries existing in the present vehicle population, this is a serious practical problem. Surveys have shown, for example, that proposed vapor sealing interface devices might fit 90% or less of existing vehicles.^{5,6}

The interface sealing devices and associated plumbing must be carefully designed to avoid overpressuring the vehicle tanks which, under extreme conditions, could produce structural tank failure and disastrous results. Further, those control methods which rely on slight positive tank pressure to force displaced gases into the removal plumbing will, if applied to the existing vehicle population, force a substantial fraction of the displaced gases out the the external tank vents. This results from the fact that a large fraction of the automobiles built before evaporative emission control use atmospheric venting systems external to the tank cap. These venting systems, of course, constitute an alternate flow path to atmosphere of the displaced vapors.

Two of the above-mentioned control concepts involve artificial cooling (direct or indirect) of the service station fuel. It must be recognized that resulting lower dispensed fuel temperature will aggravate the problem of thermal expansion of liquid fuel in the vehicle tank after fillup.

Any system which recovers the refueling emission as liquid fuel must increase the volatility of the resulting fuel mixture, since the fuel fractions existing in the vapor phase necessarily contain a disproportionate amount of light volatile material. This problem is discussed in more detail in later paragraphs.

Best Available Technique

In the judgment of General Motors, the system described in Appendix B appears to have the best potential for control of refueling emissions within the service station. This system involves a loose nozzle filler pipe interface with "vacuum cleaner" removal of the displaced gases. Removed vapors are stored on activated charcoal with eventual combined vacuum/thermal removal to the service station's fuel storage tank—"purged" vapors are condensed in the stored liquid fuel by means of a bubbler. It has been designated Service Station Charcoal Refueling Emission Control System—or SCRC for brevity.

The SCRC system appears to have several substantial advantages. First, it is applicable to all automobiles in the present and presumably future populations, both cars with and without evaporative control. (This claim of universal applicability is not known to be backed up by any field demonstration, although it appears credible from the principles involved.) The use of depression at the interface insures minimum leakage loss of vapors to the atmosphere and should prevent any loss of vapor through external venting systems on cars without evaporative emission control.

The loose fit nature of the interface protects against imposition of any significant differential pressure on the vehicle tank—either positive or negative. The SCRC system thus appears to introduce no new safety hazard to the refueling operation. It may, in fact, reduce the existing hazards by virtual elimination of gasoline vapors in the immediate ambient air of the service station. (A similar safety advantage can also be claimed for any effective refueling emission control method.) The SCRC system involves no useless incineration of the controlled fuel vapors, but rather reclaims at least a substantial fraction of the vapor for eventual use as a vehicle fuel.

The SCRC system, as well as all other proposed service station control methods, has the disadvantage of a significant increase in the cost and complexity of service station equipment. Further, there is the theoretical disadvantage, as previously mentioned, that reclamation of the major part of refueling vapors in the service station liquid fuel supply will increase the volatility of the resulting mixture. Hypothetically, one can imagine the resulting increase in volatility of gasoline at the final supply point to be a self-energizing phenomenon. The slight increase in volatility of the service station's supply will result in increased volatility of the displaced vapors at the next refueling which will provide a still higher increase in volatility of the service station's supply, and so on.

Actually, of course, the gasoline supply to the service station has a variable volatility of a generally cyclic nature because of seasonal adjustment. Consequently, the entire dynamic system must be considered to realistically assess the quantitative significance of volatility increases which might result from the SCRC system. An analysis of the volatility dynamics involved is detailed in Appendix C. It indicates that an application of the SCRC system in Los Angeles would be expected to produce a maximum volatility increase of about 0.3 psi RVP from present levels during the smog season. Considering the variation in volatility of fuels marketed elsewhere in the U.S., this increase appears to be relatively minor. Further, it is well to point out that normal marketing practice involves step changes greater than 1.0 psi RVP in the seasonal adjustments previously mentioned. The fractional RVP changes being discussed here should, therefore, be imperceptible to the vehicle operator.

VEHICLE ONBOARD CONTROL SYSTEM

Methods proposed for control of refueling emissions onboard the vehicle have included the use of a collapsible tank to eliminate the normal vapor space which exists at refueling. Hypothetically, such a tank would adjust its volume to just accommodate the liquid fuel remaining. Its volume would expand during refueling and no vapor displacement would occur. If a vapor space is to be completely avoided, fuel must be added via submerged fill. This would, consequently, involve elaborate "dry-break" hardware on either the vehicle or the dispenser nozzle, or more probably both. ("Dry-break" describes plumbing connection hardware which allows connect or disconnect of pressurized, fluid filled vessels and/or piping without loss of fluid.) Such a dry-break filler would, of course, by definition control spillage losses. Practical economical hardware for a collapsible automobile fuel tank has, to the knowledge of General Motors, never been proposed, much less demonstrated or proven durable for the normal life of an automobile.

The dominant concept for onboard control of refueling emissions involves vapor storage for later burning in the engine. This has been suggested to be merely an expansion of the now-standard vehicle evaporative control system. That concept, as well as all other methods discussed, both vehicle and service station, would require modifications to the service station dispensing nozzle to provide a seal against escape of displaced vapor through the normal nozzle-filler pipe clearance.

In the discussion that follows, it is assumed that control hardware being discussed would be applied only to new automobiles beginning with a future model year. Current production (1970 through 1973) automotive evaporative control systems will neither accommodate the additional vapor which would be imposed by refueling emission control nor the flow rate which would be required to allow normal refueling. Further, it will be clear in the subsequent discussions that retrofit of vehicles in the existing population would be impractical.

Simple Expansion of Production Controls

For the present model year, use of activated carbon storage for control of automotive evaporative emissions has become virtually standardized on domestic cars. Since the storage capacity of such systems is directly increased by the addition of more charcoal, it has been hypothesized that such an approach might provide a simple and direct route to control of refueling emissions. Unfortunately, this is not the case. Appendix D details an example of one of the more important consequences of an attempt at control by direct expansion of a production evaporative control system. This simplistic approach is shown to increase exhaust carbon monoxide emissions substantially.

The problem of increased space requirement of a four-fold expansion in charcoal volume is graphically illustrated in Appendix D. However, the most serious consequence of an attempt to use existing evaporative control hardware is the inability of this hardware to accommodate the necessarily high gas flow rate imposed by refueling. This flow rate requirement can exceed ten gallons per minute, about two orders of magnitude higher than the flow rates the existing evaporative control systems are designed to accommodate. Since this type of refueling emission control would require sealing of the refueling interface, the inadequate flow capacity of the production vapor system would result in buildup of excessive pressure which could be structurally damaging to the vehicle tank with disastrous results or, at minimum, result in "puff loss" to the atmosphere of a substantial part of the refueling emissions at nozzle disconnect.

A Practical Onboard System

Available information does suggest that the type of charcoal canister presently used for production evaporative control systems properly expanded can successfully capture and store refueling hydrocarbons at the required flow rates. Appendix D documents a test demonstration of that fact. It will be noted that four of the present charcoal canisters were used. From the point of view of "working capacity," that particular experimental expansion of vapor storage capacity appears to be marginal. The recent Scott Research program,¹ as previously indicated, shows an average refueling emission quantity of approximately 5 g/gallon of fuel installed. A 20 gallon fill would thus require additional storage capacity of at least 100 grams of hydrocarbons. The "working capacity" of the present evaporative control system is on the order of 30-35 grams as designed to meet the present regulatory requirement. "Working capacity" is defined here as the quantity of vapor emissions which can be successfully stored by a given system over an indefinite number of repeated adsorb/desorb cycles. The first element of a practical onboard refueling emission control system, then, is as expected a very large carbon canister, probably a multiple of at least four times the present system.

As previously suggested, a practical system requires drastically increased flow capacity in the tank to canister vapor plumbing. Further, this must be done without disturbing the present carefully-designed system for handling normal vehicle tank emissions, i.e., regulation of vapor flow and separation of liquid from vapor. Practically, this means a dual tank venting system is required—a refueling vent and an evaporative emission control vent. Appendix D includes a design for providing the necessary dual tank vent characteristics. It provides the necessary high flow capacity for refueling through a 3/4" vent line beginning at the filler neck to terminate at the charcoal canister. (Subsequent work suggests this diameter may be somewhat larger than required.) "Teed" at the top of the tank to the normal tank vapor control systems, the high flow capacity refueling portion of the venting system is closed after refueling by a specially designed two-seat filler pipe closure.

An additional major element of a practical onboard system is a vapor carburetor. Test data included in Appendix D illustrate that the relatively simple canister purge systems of production evaporative emission controls allow unacceptable enrichment of the engine air/fuel ratio (A/F) and accompanying increase in exhaust carbon monoxide emissions when subjected to the large increase in stored vapor imposed by refueling emissions. To prevent this unacceptable enrichment, a device must be provided which will mix a controlled amount of air with the vapor being desorbed from the carbon. One invention by General Motors of such a device is shown

in Appendix D. This device uses an electrically heated catalytically coated wire to sense the presence and amount of fuel vapor in the purge stream to provide consequent control of the amount of additional air inducted. Substantial testing was done on prototypes of this device which showed it to operate in a qualitatively proper way, but it exercised inadequate control over engine air/fuel ratio. Thus, additional development with probable increase in sophistication would be required to provide adequate vapor/air metering with even this type of device. A possible alternative for adequate control of A/F enrichment might be the use of a very large quantity of charcoal. Practical space limitation, however, would likely impose serious constraints on that approach.

As previously indicated, an onboard control system requires modification to the refueling nozzle to provide a vapor seal at the interface with the tank filler neck. This requirement, together with the safety hazards of possible tank pressurization by the refueling pump in the event of accidental restriction of the onboard vapor plumbing, dictates that a tank safety pressure relief device be added to the tank. Such a safety device is included in present production GM fuel systems, but is installed in the filler cap.

The final schematic sketch of Appendix D includes all of the elements of a practical onboard system previously described. While most of the elements of such a system have been designed and tested by General Motors, some only partially successfully, it is emphasized that a complete operational system has yet to be demonstrated. We are confident, however, that given adequate development time, a technically successful system could be built. Whether a system of this type would be cost effective or even economically feasible, however, is open to serious question. When the regional nature of actual refueling emission control needs are considered, service station control seems clearly preferable.

ACHIEVABLE CONTROL AND TEST PROCEDURE

We believe that all practical control methods which have been conceived to date include the probability of some loss in refueling emission to the atmosphere either in the form of vapor, liquid or both. The inevitability of some losses, however minute, at the time of filler nozzle connect or disconnect appears difficult to deny. There is, consequently, need for concern over the amount of such losses which would be allowed in a regulatory control program. The need to specify amount of losses to be allowed further implies requirement for a test procedure to properly define the allowable emissions. No accepted procedure for measurement of "controlled" refueling emissions exists at the date of this writing. There is an activity under way by a subcommittee of the Society of Automotive Engineers Automotive Emissions Committee to develop such a test procedure. In the absence of an established test procedure, and therefore, absence of experimental data on effectiveness of control, the following emission estimates are based on the assumption that any control system would be 90% effective in controlling normal automobile refueling emissions.

EFFECT OF CONTROL ON LOS ANGELES ATMOSPHERE

The curves of Appendix E show the estimated trend in total hydrocarbon emissions to the Los Angeles Basin atmosphere resulting from the aggregate of all automotive refueling operations. It is shown that imposition of 90% control of refueling emissions at either the vehicle or the service station quickly results in substantial reduction in these total emissions to the atmosphere. While the two methods of control result in essentially the same total emissions by the year 1990, service station control is much more effective prior to the early 1980's than new car control. This is particularly significant in view of the mid-1970's target for achievement of air quality standards. It must be emphasized, of course, that until the mid-1980's, when a large number of vehicles are equipped with extremely stringent exhaust hydrocarbon control, the refueling hydrocarbon emissions represent a small fraction of the total automotive hydrocarbon emissions to Los Angeles Basin atmosphere.

CONCLUSIONS

Control of automobile refueling hydrocarbon emissions appears to be technically feasible either by control hardware at the service station or onboard the vehicle. The latter, however, can only be considered as practically applicable to new vehicles beginning some future model year. Either control approach would involve substantial technology penalties beyond current hardware and both would require some additional service station hardware. A service station control system is available which would impose control on the refueling emissions from all cars (including transient vehicles) and should involve minimum penalty to the motoring public of the State of California. This approach has potential for practical regionalization of control coupled with very rapid reduction in total refueling emissions.

REFERENCES

1. Malcolm Smith, "Investigation of Passenger Car Refueling Losses—Second Year Program," Scott Research Laboratories, Inc., San Bernardino, California, September 1, 1972.
2. "Cumulative Regulatory Effects on the Cost of Automotive Transportation (RECAT)" Final Report of the Ad Hoc Committee, Prepared for Office of Science and Technology, February 28, 1972.
3. Richard A. Fusco and G. M. Goyak, Calgon Corp., "The Use of Activated Carbon for Control of Gasoline Vapor Losses," Presentation to SAE Fuel Supply Systems Committee, May 23, 1972.
4. "A Cost-Effectiveness Appraisal of Alternate Systems for No-Lead Safeguard and Refueling Vapor Containment," A Presentation Prepared for the Environmental Protection Agency by Ford Motor Company, October 28, 1971.
5. "Vapor Emission Control in Automobile Fueling," A Research Study by Gilbarco, May, 1972.
6. W. B. Hansel, Sun Oil Company, Letter to L. P. Ziegler, Jr., SAE Inc., East Detroit, Mich., Nov. 24, 1971; Enclosing U.S. Patent 3,566,928.

APPENDIX A GASOLINE FILLER NOZZLE HEAT EXCHANGER FOR REFUELING EMISSION CONTROL

INTRODUCTION

If the vapor displaced from a vehicle fuel tank during refueling, is cooled as it is displaced, some of the vapor might be condensed and recovered. Liquid fuel in underground storage tanks is sometimes cooler than the local ambient temperature and represents a possible cold source for condensing the vapor.

Investigations have been made of a heat exchanger as a part of the gasoline filler nozzle. As shown in Figure A-1, the heat exchanger is arranged so that all vapor displaced from the vehicle tank flows through it and is cooled by the liquid fuel flowing to the vehicle tank. Two different heat exchangers have been built and tested as illustrated in the photographs of Figures A-2 and A-3.

CONCLUSIONS

1. Underground tank storage temperatures are not low enough to condense an appreciable fraction of the vapor displaced from vehicular tanks during fill.
2. As vapor is displaced from vehicular tanks during fill, "splash" cooling in the filler neck cools the vapor, condensing approximately 75% as much as an ideal heat exchanger could condense. (This conclusion appears to apply to most passenger cars but probably not to station wagons with their short filler necks.)
3. Considering the above two factors, there is very little benefit gained with a heat exchanger constructed as part of the filler neck.

HEAT EXCHANGER DESIGN

The sketch in Figure A-1 is a section view of the design as built and tested. Liquid fuel going to the vehicle tank flows through a central pipe. A concentric shell provides a housing for the heat exchanger; this shell is fitted with an adapter that seals to the vehicle filler neck. Displaced vapor flows through the outer annulus and is cooled by the fins.

Two different heat exchangers were built. The smaller is shown in Figure A-2. The heat exchanger portion is 8 inches long and 1.22 outside diameter. The larger is shown in Figure A-3. The heat exchanger portion is 10 inches long and 2.1 outside diameter.

The samples were built of brazed aluminum, although a production proposal would probably require aluminum clad steel inner and outer pipes with brazed aluminum fins.

TEST METHOD

Production General Motors gasoline tanks were used for these tests. From 1 to 2-1/2 gallons of gasoline were placed in the tank, the tank was soaked in a 100°F wind tunnel. Reid Vapor Pressures of the fuel in the tank after the soak were measured for some test runs. A filler nozzle with heat exchanger as described above and a special collection bonnet (Figure A-4) was attached to the gasoline tank. Twenty gallons of fuel were metered to the tank at a flow rate of approximately 7.5 gal/min.

The displaced air/vapor mixture was collected in a tube and routed to three new carbon canisters in parallel. The canisters were weighed before and after the test to determine the amount of gasoline collected. In some tests, a second group of canisters was added downstream of the first group. This second group showed no weight gain, indicating that the first group collects essentially all the fuel contained in the air/vapor mixture.

DATA INTERPRETATION

Two types of data were obtained: pertinent temperatures during the fill procedure and the total amount of fuel collected in the carbon canister during a test run.

The temperature data, taken with equilibrium saturation data for air/gasoline, permit calculation of the pounds of gasoline that should be collected in the canister; the carbon canisters, of course, show what was collected during a given run.

The calculated data allows a more complete analysis, in that calculations can be made for vapor quantities at any point in the flow schematic and at any time during the fill procedure. The two sets of data do not agree in magnitude, but both lead to the conclusions reported: that liquid fuel temperatures are not low enough to condense a major portion of the displaced vapor and that splash cooling already condenses most of what might be condensed.

The disagreement in the data is that less is collected in the canisters than is calculated from equilibrium curves. The amount collected varies from about 65% to 85% of that calculated. Three possible reasons for the difference are evident: (1) the saturation data available are not representative of the actual fuel used; (2) the air and gasoline in the tank were not at equilibrium when the fill started; and (3) condensation in the tube between the gas tank and the carbon canister.

None of these seems to be of magnitude to account for the discrepancy and it therefore remains unexplained.

For reference, Figure A-5 shows saturation curves for gasoline of various vapor pressures as used for calculations. The original data were developed by GM Engineering Staff* and recalculated to show pounds of gasoline in 20 gallons of air/vapor mixture as a function of mixture temperature and Reid Vapor Pressure.

TEST RESULTS, MEASURED TEMPERATURES, AND CALCULATED FUEL QUANTITIES

Figure A-6 shows a test of the larger heat exchanger (Figure A-3). Temperatures are plotted vs. gallons of fill. The curve VAPOR

*In accordance with the method of D. T. Wade, "Factors Influencing Vehicle Evaporative Emissions," SAE paper #670126, January 1967.

LEAVING TANK shows the temperature out of the gas tank, into the heat exchanger. The curve VAPOR LEAVING HEAT EXCHANGER shows the temperature out of the heat exchanger as being dumped to the atmosphere (or to the carbon canisters in the test procedure).

The air/vapor mixture in the 102°F at start of test. For RVP = 10, 20 gallons of mixture contains .375 pounds of gasoline; if the mixture were displaced to the atmosphere at this temperature, the entire .375 pounds would be released to the atmosphere. However, the VAPOR LEAVING TANK dropped to 74°F after 2.5 gallons of fill, to 70°F after 5 gallons, and approximately stabilized at 66°F after 7-1/2 gallons. The gasoline content of the air/vapor mixture at these temperatures represents the actual quantity of gasoline released to the atmosphere with no heat exchanger for this particular fill. Calculation shows this to be .235 pounds.

Figure A-7 plots these data on the basis of POUNDS FUEL FOR 20 GALLON FILL vs. GALLONS ADDED. The top curve represents the .375 pounds of gasoline in the vapor before the filling started and, as discussed above, would be displaced to the atmosphere if no condensation occurs. The second curve, labeled ".235" represents the fuel in the vapor at each instant as it leaves the tank, the area under the curve is the total pounds of gasoline in the 20 gallons of air/vapor mixture and is the .235 pounds referred to. The difference between the two is .140 pounds and represents the fuel condensed by splash cooling in the filler neck.

The bottom curve, labeled ".187" represents the pounds of gasoline in 20 gallons of air/vapor mixture at the temperature of the gasoline being added (in this instance, ranging between 57°F and 62°F). This represents the minimum pounds of gasoline per 20 gallon fill released to the atmosphere for perfect condensation at these temperatures.

Therefore, for perfect condensation at the given temperatures (approximately 102°F tank, 59°F fill gasoline) it is possible to condense only .187 ÷ .375 = 50% of the vapor in the tank.

For test purposes, liquid fuel at approximately 60°F and 100°F vehicle tank were assumed. Splash cooling condensed (.375 - .235) ÷ (.375 - .187) = 74% of the maximum condensation possible at the selected temperatures. This is only (.140 ÷ .375) = 37% of the vapor in the tank at the time of fill.

The intermediate curve, labeled ".209" represents the temperature leaving the heat exchanger. As indicated in the figure, splash cooling left little for the heat exchanger to condense; the heat exchanger then condensed approximately half of what was available to it.

It should be emphasized that most or all of the splash cooling referred to occurs in the filler neck and, therefore, probably applies to most General Motors passenger cars but not to station wagons.

TEST RESULTS, FUEL QUANTITIES AS COLLECTED IN CARBON CANISTERS

Three different types of tests were run measuring the fuel collected in carbon canisters.

1. An attempt was made to displace the air/vapor mixture from the tank without cooling, to measure the gasoline contained in the tank vapor.
2. Runs were made with normal fill and no heat exchanger, to measure the gasoline contained in the air/vapor mixture as normally released to the atmosphere.
3. Runs were made with the heat exchanger to measure the gasoline in the air/vapor mixture after passing through the heat exchanger.

1. Vapor in Tank at Start of Fill

A deflated 40 gallon plastic bag was placed in the gas tank, and 2.7 gallons of gasoline were placed in the tank outside of the bag and soaked to 100° vapor temperature. The fill nozzle (with no heat exchanger) was attached to the bag to flow liquid into the bag; the collection device collected the displaced air/vapor mixture from the tank (from the space outside the bag). This arrangement prevented splash mixing of the gasoline flowing into the tank with

the vapor flowing from the tank. Heated gasoline was used for the fill to further reduce heat transfer; its temperature dropped from 99°F at start of fill to 86°F at end of fill.

Even with these precautions, the vapor leaving the tank cooled slightly to 93°F at end of fill (and was actually half way between the initial vapor temperature and the input gas temperature throughout the fill). Temperatures are plotted in Figure A-8.

At Reid Vapor Pressure of 10.5, and the start vapor temperature of 100°F, there were .385 pounds of fuel in the air/vapor mixture in the tank at start. Calculating along the temperature curve, .361 pounds of fuel were in the vapor as it left the tank. However, only .240 pounds were collected in the carbon canisters (weight change in the secondary canister was zero) or 67% of that calculated.

2. Vapor Leaving Tank During Normal Fill, No Heat Exchanger

Figure A-9 shows temperatures for a run with no heat exchanger. The curve VAPOR LEAVING TANK shows the temperatures measured. Calculation for these temperatures indicates that .253 pounds of fuel is in the 20 gallons of air/vapor mixture leaving the tank. The carbon canisters collected only .168 or 65%. This was the lowest fraction collected during the test series.

Comparing the .168 to the .240 collected in the plastic bag procedure described above shows that splash cooling condensed (.240 - .168) ÷ .240 = 30% of the vapor originally in the tank as indicated by the carbon canister method. Calculated values are (.375 - .253) ÷ .375 = 33%. Thus, while the quantities collected are less than those calculated, the conclusions are in agreement.

3. Vapor Leaving Heat Exchanger

These tests were conducted similarly to those under item 2 above, except that the heat exchanger was used and the carbon canister measured the gasoline in the air/vapor mixture as it left the heat exchanger. Typical temperatures are shown on Figure A-6 and calculated gasoline quantities on Figure A-7.

Ideally, the difference between these tests and those under item 2 represents the gasoline condensed in the heat exchanger. In practice, after condensation by splash cooling, the quantity remaining to be condensed in the heat exchanger was small and was obscured by test variations.

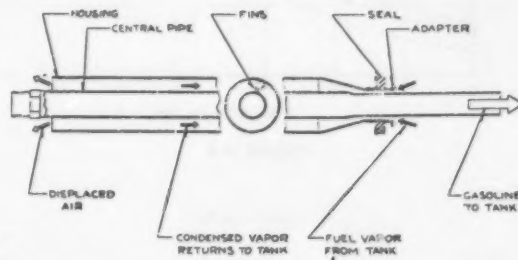


FIGURE A-1



FUEL NOZZLE WITH SMALL HEAT EXCHANGER FOR VAPOR CONDENSATION
FIGURE A-2



FUEL NOZZLE WITH LARGE HEAT EXCHANGER
FOR VAPOR CONDENSATION
FIGURE A-3



FUEL NOZZLE WITH HEAT EXCHANGER
AND COLLECTION BONNET
FIGURE A-4

AMOUNT OF GASOLINE VAPOR IN
20 GALLONS AIR-VAPOR MIXTURE

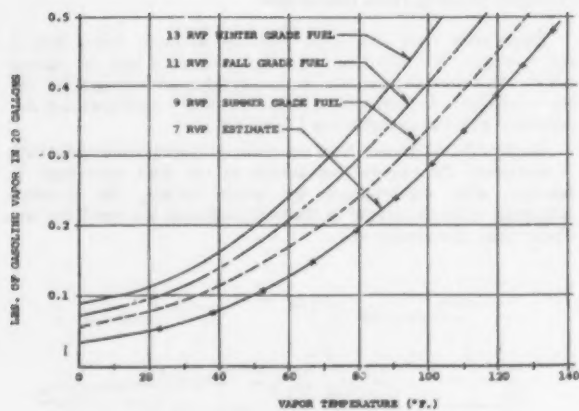


FIGURE A-5

LARGE HEAT EXCHANGER

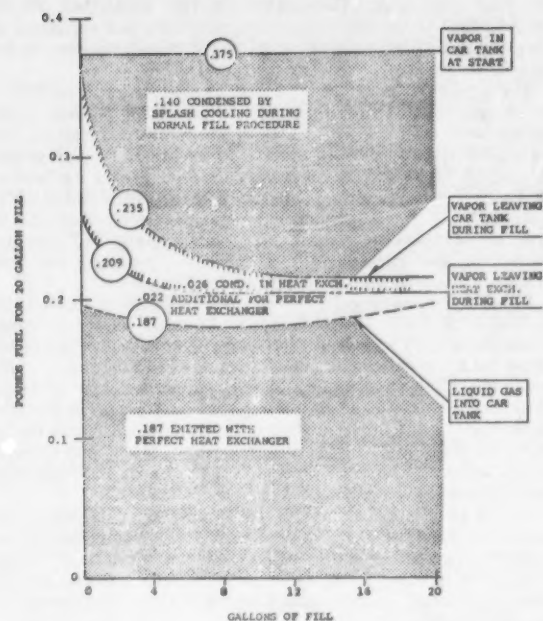


FIGURE A-7

100 F. EQUILIBRIUM FILL

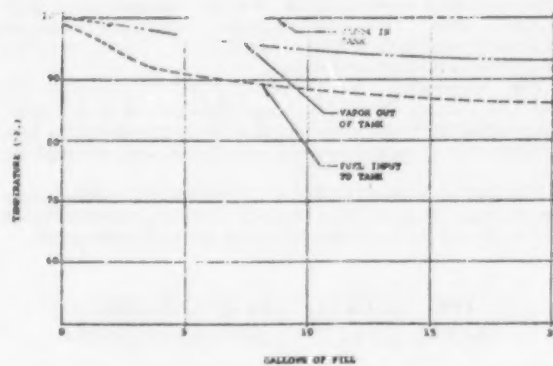


FIGURE A-8

LARGE HEAT EXCHANGER

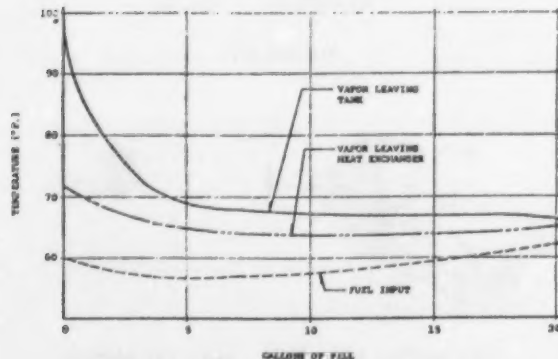


FIGURE A-6

BASISLINE - LARGE HEAT EXCHANGER

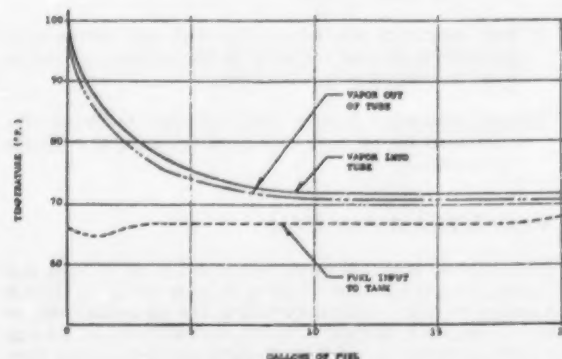


FIGURE A-9

APPENDIX B

SERVICE STATION ACTIVATED CARBON REFUELING EMISSION CONTROL SYSTEM (SCRC)

Use of activated carbon for storage of vehicle refueling vapor emissions has been proposed as an obvious evolution of the now-widespread use of carbon for control of vapor emissions from vents of automotive fuel supply systems. (See reference 3 of the main body of this paper.) As with the onboard application, however, the charcoal serves only as a storage intermediary. Stored hydrocarbon vapors must eventually be removed from the carbon for ultimate disposal elsewhere. In the case of the onboard system, that ultimate disposal point is the engine combustion process.

Refueling vapors stored on a service station charcoal system can be similarly disposed of by incineration. The carbon stored vapors could also be removed through air purge as with the onboard system into the service station tank. In either case, the carbon system would serve only as an accumulator to facilitate the final disposition to avoid the problems of high frequency, intermittent disposal of small amounts of vapors as they are generated with each individual refueling operation.

Actually, the charcoal approach has a much more important advantage in that charcoal separates hydrocarbons from a stream containing hydrocarbon vapors and air. Refueling emission gases, of course, do contain large percentages of air. With this separation function performed by the charcoal at the time of emission, the possibility is provided that nearly pure hydrocarbon material can be ultimately disposed of to the service station storage tank. While air purge of stored vapors from activated carbon has been established to be convenient and practical, that method applied to service station storage tank disposal would aggravate the difficulties in controlling breathing losses from the storage tank through attendant introduction of excess air.

Reference 3 discusses the possibility that hydrocarbon vapors stored on activated carbon can be removed by imposing a vacuum on the carbon, higher vacuums resulting in more rapid and more complete purge. Application of heat to the carbon can facilitate the vacuum purge process. Figure B-1 illustrates an SCRC system which has been developed by the RB&W Company* of Port Chester, New York. This system bubbles the vacuum purge vapors into the service

Simplified Schematic RB&W - Tokheim Refueling Emission Control System

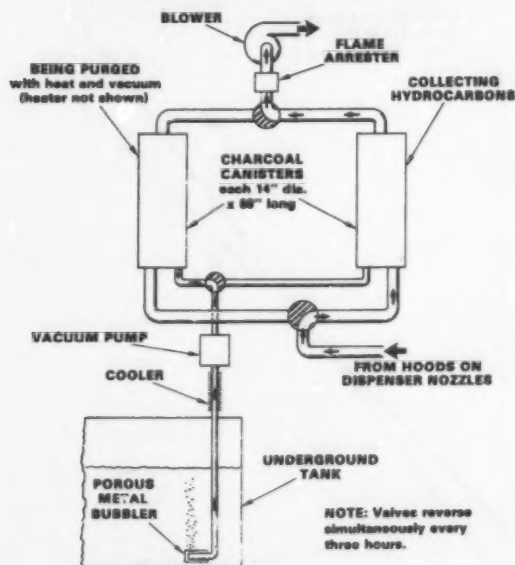


FIGURE B-1

*Available information indicates that patents associated with this system are currently assigned to the United Chemical Corporation of Tulsa, Oklahoma.

station's fuel supply, thereby, it is claimed, dissolving a very high fraction of the recovered hydrocarbons in the liquid fuel supply.

As indicated in Figure B-1, this system employs a loose-fit hood on the filler nozzle, thus collecting the refueling emissions via the "vacuum cleaner" approach which has been previously discussed. Again, the ability of activated carbon to separate hydrocarbons from an air stream allows the attendant induction of substantial amounts of excessive air without compromising the hydrocarbon control effectiveness.

APPENDIX C

THE EFFECT OF DISSOLVED REFUELING VAPORS ON THE REID VAPOR PRESSURE OF STORAGE TANK FUEL

ABSTRACT

Some service station refueling emission control designs dissolve the expelled vapor in the underground storage tank fuel. This paper analyzes the effect of these vapors upon the storage tank fuel Reid Vapor Pressure. The analysis cycles several typical storage tanks through discharge-refill cycles for one year. The Reid Vapor Pressure is calculated at the end of each day. The results indicate that the tank will stabilize at a Reid Vapor Pressure no greater than 0.3 psi above present conditions. The equations, computer program, and numerical results are presented.

INTRODUCTION

The interest in refueling emissions was precipitated by the San Diego County ordinance calling for their control. These emissions are significant, particularly when considering 1976 hydrocarbon emission levels. It has been estimated that a car equipped with a 1976 exhaust emission control system will emit a similar amount of hydrocarbon emissions during the refueling process as it will for the same amount of fuel burned in the engine (0.396 g/mi refuel v.s. 0.41 g/mi Federal limit).

Several service station systems have been proposed. One has been built which dissolves the refuel emissions in storage tanks. This paper calculates the resulting Reid Vapor Pressure (RVP) for these conditions on a daily basis. Seasonal ambient temperature and fuel RVP changes are considered. A time sharing computer terminal was used for the actual calculations. The assumptions, equations, computer program and numerical results will be discussed.

CONCLUSIONS

1. The storage tank fuel RVP will stabilize at a value no greater than 0.3 psi above typical tanks as they are now refueled.
2. The RVP variance from present conditions is no greater than 0.3 psi even at seasonal RVP fuel changes.
3. Reducing the daily gallonage sales for a given storage tank increased the RVP stabilization point. However, it did not exceed 0.3 psi for the conditions selected. The increase was primarily caused by the lower refill point of the storage tank.

DISCUSSION

Problem was set up on a daily basis. The assumptions are as follows:

1. The grams of expelled refuel vapor will be predicted by the equations presented in the CRC-APRAC-CAPE-9 Report #2 and are shown on Figure C-1. (See Reference 1 in the main body of this paper.)

- The inputs to the CAPE-9 equations will be derived from seasonal fuel RVP and average daily ambient temperature data.
- The expelled vapors are 50% butane and 50% pentane and have the following properties: Specific gravity - 0.61; RVP, psi - 32.0.
- All of the refuel vapors will be dissolved in the "Regular" fuel storage tank (largest sales volume fuel).
- The RVP changes will be calculated as per the classical mixing formula shown on Figure C-1.

The temperature data plots from which assumption 2 was made are shown on Figure C-2. The scatter of the dispensed fuel v.s. ambient temperature plot was believed to be caused by variances in ambient temperature. In other words, a rapid change in ambient temperature would result in less temperature change of the underground fuel. Hopefully, future CRC data will clarify this point.

The variables were as follows:

- Total daily sales - gallons
- "Regular" fuel daily sales - gallons
- Capacity of "Regular" storage tank - gallons
- Refill point of "Regular" storage tank - gallons
- Seasonal RVP fuel schedule - for Los Angeles
- Average daily displaced vapor temperature - °F
- Average daily dispensed fuel temperature - °F

The underground storage tank was then cycled through its normal operation until one year in time had passed.

The calculations for one cycle are as follows: The grams of vapor emitted during one day's refueling operation were calculated from the daily sales, average ambient temperature and the initial RVP of the dispensed fuel. The equation and data on Figures C-1, 2 and 3 respectively were used. The ambient temperatures were taken from U.S. Weather Bureau data. The RVP schedule is currently typical. The daily grams of vapor emitted were converted to gallons of condensed liquid by using a specific gravity of 0.61 and 3784.5 cc/gal. Next, the gallons of condensed vapor were poured into the "Regular" storage tank after the daily sales had been subtracted and the resulting RVP calculated as per Figure C-1. The total gallons of this mixture were then compared to the refill level, which was

picked at 1.5 times the daily "Regular" gallonage sales. If the level of the storage tank was above the indicated refill point, the above procedure was repeated until the refill point was reached. The gallons and RVP of the fuel remaining in the tank were then noted and the tank refilled with the seasonal RVP fuel. The RVP of the full tank was again calculated as per Figure C-1. The full tank gallons and RVP were noted as before.

A similar analysis was done of the same tank but without the refuel vapor addition. The only RVP changes of the storage tank for this condition occurred at the seasonal fuel changes. The differences between the two analyses on a day-to-day basis gives the refuel vapor effect on storage tank RVP.

A print-out of the program and definition of terms is shown on Figure C-6 and C-7.

The results for an analysis as described above for three service station conditions are given on Figure C-4. A sales rate of 2600 gallons per day and a seasonally blended fuel are used for condition 1. Condition 2 is the same as 1 except for a constant 9.0 psi RVP fuel. A sales rate of 900 gallons per day and a seasonally blended fuel is used for condition 3. The entire annual computer listing for condition 3 is shown on Figure C-5.

In all cases, the RVP change is less than 0.3 psi. Also, note that the change in RVP from present conditions was higher for the 900 gallon sales example. This was caused primarily by the lower refill point of the storage tank. There was little difference between the constant 9.0 RVP and seasonal RVP fuel examples.

It appears that for a given storage tank, the daily sales volume and/or the refill point affects the equilibrium RVP. No attempt was made to optimize the conditions to minimize the RVP change. The results presented are typical of refill points currently in use. However, it would be possible to calculate the optimum point based on any given set of operating conditions.

It is somewhat surprising to find the program yielding stabilized values as low as indicated (+0.3 psi RVP). It was noted that the day-to-day increases in RVP (or boost) were relatively uniform even as storage tank RVP increased. The dilution effect of filling the tank became more pronounced, however, as the storage tank fuel RVP increased from the refuel RVP. Equilibrium will be established when the boost and dilution changes are equal. A detailed analysis of this was made and is given on Figure C-8.

Excessive storage tank fuel RVP increases or changes do not appear to be a problem with this technique.

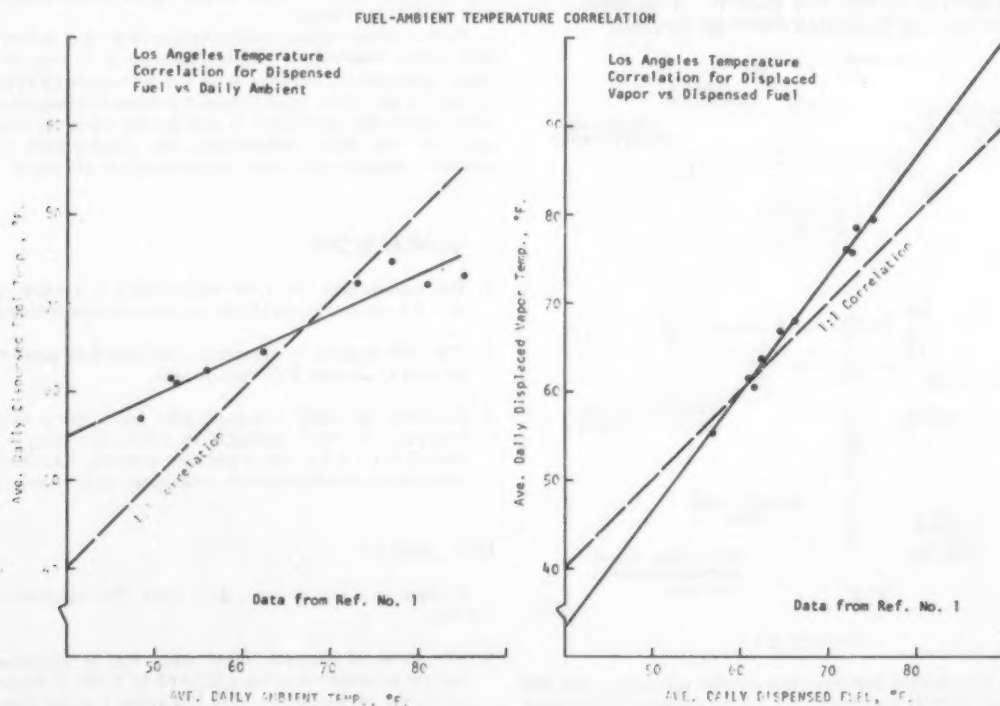


FIGURE C-2

SEASONAL CHANGES OF FUEL RVP
AND AMBIENT TEMPERATURE FOR LOS ANGELES

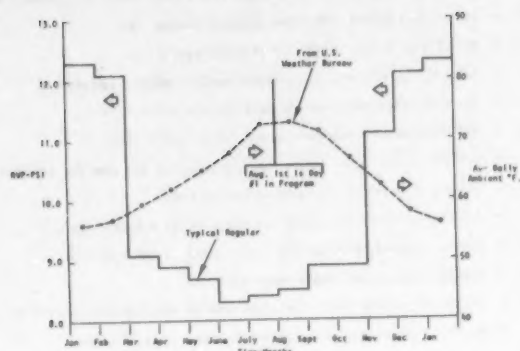


FIGURE C-3

ANNUAL RVP RESULTS FOR STORAGE TANK FUEL-ENTIRE YEAR

CONDITIONS:

Total daily sales - 900 gal. Regular storage tank refill point - 1026 gal.
Regular daily sales-684 gal. RVP schedule - See Figure 3
Regular storage tank capacity - 6000 gal. Day #1 is August 1

DAY/RVP-DELIV	GALLONS	RVP	PSI/STD	CHANGE
0	542,990	0.6005	0.5	.108847
0	0.5	0.6000	0.5	1.7600E-2
16	542,987	0.7187	0.5	.012171
16	0.5	0.6000	0.5	1.9187E-2
24	542,987	0.8194	0.5	.010344
24	0.5	0.7187	0.5	1.9199E-2
32	542,36	0.9104	0.5	.010356
32	0.9	0.8000	0.0640	.017051
40	542,299	0.00195	0.0640	1.0961E-2
40	0.9	0.9144	0.079	.016190
48	542,099	0.0111	0.0865	1.0961E-2
48	0.9	0.9144	0.09973	.012914
56	542,784	0.1124	0.09973	1.9242E-2
56	0.9	0.9100	0.09990	.000000
64	542,474	0.0001	0.0	1.0814E-2
64	0.9	1.0137	0.4	.007507
72	542,144	0.0000	0.0	1.0179E-2
72	0.9	1.0049	0.0	.004973
80	542,006	0.11742	0.4	1.7742E-2
80	0.9	0.0000	0.0	.000000
88	542,463	0.0000	0.0	1.7601E-2
88	0.9	0.91747	0.4	.000710
96	542,123	0.0000	0.0	1.0202E-2
96	11.1	0.0000	10.064	.024044
104	542,549	11.1132	10.064	1.0070E-2
104	11.1	0.0000	11.001	.010479
112	542,571	11.1134	11.001	2.0104E-2
112	11.1	0.0000	11.0005	.000000
120	542,433	11.1144	11.0005	2.0004E-2
120	11.1	0.0000	11.0000	.010000
128	542,438	11.1144	11.0000	1.1117E-2
128	11.1	0.0000	12.012	.000000
136	542,624	12.012	12.012	.000000
136	12.1	0.0000	12.012	.000000
144	542,701	12.012	12.012	.000000
144	12.1	0.0000	12.012	.000000
152	542,792	12.012	12.012	.000000
152	12.1	0.0000	12.012	.000000
160	542,664	12.012	12.012	.000000
160	12.1	0.0000	12.012	.000000
168	542,111	12.012	12.012	.000000
168	12.1	0.0000	12.012	.000000
176	542,170	12.012	12.012	.000000
176	12.1	0.0000	12.012	.000000
184	542,111	12.012	12.012	.000000
184	12.1	0.0000	12.012	.000000
192	542,154	12.012	12.012	.000000
192	12.1	0.0000	12.012	.000000
200	542,102	12.012	12.012	.000000
200	12.1	0.0000	12.012	.000000
208	542,154	12.012	12.012	.000000
208	12.1	0.0000	12.012	.000000
216	542,111	12.012	12.012	.000000
216	12.1	0.0000	12.012	.000000
224	542,154	12.012	12.012	.000000
224	12.1	0.0000	12.012	.000000
232	542,111	12.012	12.012	.000000
232	12.1	0.0000	12.012	.000000
240	542,174	12.012	12.012	.000000
240	12.1	0.0000	12.012	.000000
248	542,111	12.012	12.012	.000000
248	12.1	0.0000	12.012	.000000
256	542,154	12.012	12.012	.000000
256	12.1	0.0000	12.012	.000000
264	542,111	12.012	12.012	.000000
264	12.1	0.0000	12.012	.000000
272	542,154	12.012	12.012	.000000
272	12.1	0.0000	12.012	.000000
280	542,111	12.012	12.012	.000000
280	12.1	0.0000	12.012	.000000
288	542,154	12.012	12.012	.000000
288	12.1	0.0000	12.012	.000000
296	542,111	12.012	12.012	.000000
296	12.1	0.0000	12.012	.000000
304	542,154	12.012	12.012	.000000
304	12.1	0.0000	12.012	.000000
312	542,111	12.012	12.012	.000000
312	12.1	0.0000	12.012	.000000
320	542,154	12.012	12.012	.000000
320	12.1	0.0000	12.012	.000000
328	542,111	12.012	12.012	.000000
328	12.1	0.0000	12.012	.000000
336	542,154	12.012	12.012	.000000
336	12.1	0.0000	12.012	.000000
344	542,111	12.012	12.012	.000000
344	12.1	0.0000	12.012	.000000
352	542,154	12.012	12.012	.000000
352	12.1	0.0000	12.012	.000000
360	542,111	12.012	12.012	.000000
360	12.1	0.0000	12.012	.000000
368	542,154	12.012	12.012	.000000
368	12.1	0.0000	12.012	.000000
376	542,111	12.012	12.012	.000000
376	12.1	0.0000	12.012	.000000
384	542,154	12.012	12.012	.000000
384	12.1	0.0000	12.012	.000000
392	542,111	12.012	12.012	.000000
392	12.1	0.0000	12.012	.000000
400	542,154	12.012	12.012	.000000
400	12.1	0.0000	12.012	.000000

FIGURE C-5

ANNUAL RVP RESULTS FOR STORAGE TANK FUEL

Condition 1

Total Daily Sales 2600 gallon
Regular Daily Sales 1976 gallon
Regular Storage Tank Capacity 6000 gallon
Regular Storage Tank Refill Point 2964 gallon
RVP Schedule - See Figure 3
Day #1 is August 1

Maximum RVP Increase and Variance +.154 psi

Condition 2

Same as Condition 1 except constant 9.0 psi RVP fuel
Maximum RVP Increase and Variance +.150 psi

Condition 3

Total Daily Sales 900 gallon
Regular Daily Sales 684 gallon
Regular Storage Tank Capacity 6000 gallon
Regular Storage Tank Refill Point 1026 gallon
RVP Schedule - See Figure 3
Day #1 is August 1

Maximum RVP Increase and Variance +.231 psi

FIGURE C-4

DEFINITION OF PROGRAM TERMS

Program for Predicting the Effect of Dissolved
Refueling Vapors on the RVP of Storage Tank Fuel

```

10 LET B=10000
20 LET C=100000
30 LET D=10.70
40 LET E=2500000
50 LET G=1.5475
70 LET V=10.5
80 LET W=10
90 LET X=10.75
100 LET Y=1000
110 LET Z=10000
120 LET A=10000
130 LET P=50000
140 LET B=10000
150 LET L=10000
160 LET J=10000
170 PRINT "ENGINE TATION FUEL VOLATILITY"
180 PRINT "AT EFFECTED T. PERPELLING EMISSION CONTROL"
190 PRINT
200 PRINT "NO. 1 FUEL INLET TEMPERATURE"
210 PRINT
220 PRINT "NO. 2 FUEL INLET TEMPERATURE"
230 PRINT
240 LET A=10000
250 LET B=10000
260 LET C=10000
270 LET D=10000
280 LET E=10000
290 LET F=10000
300 IF G=10 THEN G=10
310 LET A=10000
320 LET B=10000
330 LET C=10000
340 IF D=10 THEN D=10
350 IF E=10 THEN E=10
360 IF F=10 THEN F=10
370 IF G=10 THEN G=10
380 IF H=10 THEN H=10
390 IF I=10 THEN I=10
400 IF J=10 THEN J=10
410 IF K=10 THEN K=10
420 IF L=10 THEN L=10
430 IF M=10 THEN M=10
440 IF N=10 THEN N=10
450 LET V=10.5
460 LET W=10
470 LET X=10.75
480 LET Y=1000
490 LET Z=10000
500 LET A=10000
510 LET B=10000
520 LET C=10000
530 LET D=10000
540 LET E=10000
550 LET F=10000
560 LET G=10000
570 LET H=10000
580 LET I=10000
590 LET J=10000
600 LET K=10000
610 LET L=10000
620 LET M=10000
630 LET N=10000
640 LET O=10000
650 LET P=10000
660 LET Q=10000
670 LET R=10000
680 LET S=10000
690 LET T=10000
700 LET U=10000
710 LET V=10000
720 LET W=10000
730 LET X=10000
740 LET Y=10000
750 LET Z=10000
760 LET A=10000
770 LET B=10000
780 LET C=10000
790 LET D=10000
800 LET E=10000
810 LET F=10000
820 LET G=10000
830 LET H=10000
840 LET I=10000
850 LET J=10000
860 LET K=10000
870 LET L=10000
880 LET M=10000
890 LET N=10000
900 LET O=10000
910 LET P=10000
920 LET Q=10000
930 LET R=10000
940 LET S=10000
950 LET T=10000
960 LET U=10000
970 LET V=10000
980 LET W=10000
990 LET X=10000
1000 LET Y=10000
1010 LET Z=10000
1020 LET A=10000
1030 LET B=10000
1040 LET C=10000
1050 LET D=10000
1060 LET E=10000
1070 LET F=10000
1080 LET G=10000
1090 LET H=10000
1100 LET I=10000
1110 LET J=10000
1120 LET K=10000
1130 LET L=10000
1140 LET M=10000
1150 LET N=10000
1160 LET O=10000
1170 LET P=10000
1180 LET Q=10000
1190 LET R=10000
1200 LET S=10000
1210 LET T=10000
1220 LET U=10000
1230 LET V=10000
1240 LET W=10000
1250 LET X=10000
1260 LET Y=10000
1270 LET Z=10000
1280 LET A=10000
1290 LET B=10000
1300 LET C=10000
1310 LET D=10000
1320 LET E=10000
1330 LET F=10000
1340 LET G=10000
1350 LET H=10000
1360 LET I=10000
1370 LET J=10000
1380 LET K=10000
1390 LET L=10000
1400 LET M=10000
1410 LET N=10000
1420 LET O=10000
1430 LET P=10000
1440 LET Q=10000
1450 LET R=10000
1460 LET S=10000
1470 LET T=10000
1480 LET U=10000
1490 LET V=10000
1500 LET W=10000
1510 LET X=10000
1520 LET Y=10000
1530 LET Z=10000
1540 LET A=10000
1550 LET B=10000
1560 LET C=10000
1570 LET D=10000
1580 LET E=10000
1590 LET F=10000
1600 LET G=10000
1610 LET H=10000
1620 LET I=10000
1630 LET J=10000
1640 LET K=10000
1650 LET L=10000
1660 LET M=10000
1670 LET N=10000
1680 LET O=10000
1690 LET P=10000
1700 LET Q=10000
1710 LET R=10000
1720 LET S=10000
1730 LET T=10000
1740 LET U=10000
1750 LET V=10000
1760 LET W=10000
1770 LET X=10000
1780 LET Y=10000
1790 LET Z=10000
1800 LET A=10000
1810 LET B=10000
1820 LET C=10000
1830 LET D=10000
1840 LET E=10000
1850 LET F=10000
1860 LET G=10000
1870 LET H=10000
1880 LET I=10000
1890 LET J=10000
1900 LET K=10000
1910 LET L=10000
1920 LET M=10000
1930 LET N=10000
1940 LET O=10000
1950 LET P=10000
1960 LET Q=10000
1970 LET R=10000
1980 LET S=10000
1990 LET T=10000
2000 LET U=10000
2010 LET V=10000
2020 LET W=10000
2030 LET X=10000
2040 LET Y=10000
2050 LET Z=10000
2060 LET A=10000
2070 LET B=10000
2080 LET C=10000
2090 LET D=10000
2100 LET E=10000
2110 LET F=10000
2120 LET G=10000
2130 LET H=10000
2140 LET I=10000
2150 LET J=10000
2160 LET K=10000
2170 LET L=10000
2180 LET M=10000
2190 LET N=10000
2200 LET O=10000
2210 LET P=10000
2220 LET Q=10000
2230 LET R=10000
2240 LET S=10000
2250 LET T=10000
2260 LET U=10000
2270 LET V=10000
2280 LET W=10000
2290 LET X=10000
2300 LET Y=10000
2310 LET Z=10000
2320 LET A=10000
2330 LET B=10000
2340 LET C=10000
2350 LET D=10000
2360 LET E=10000
2370 LET F=10000
2380 LET G=10000
2390 LET H=10000
2400 LET I=10000
2410 LET J=10000
2420 LET K=10000
2430 LET L=10000
2440 LET M=10000
2450 LET N=10000
2460 LET O=10000
2470 LET P=10000
2480 LET Q=10000
2490 LET R=10000
2500 LET S=10000
2510 LET T=10000
2520 LET U=10000
2530 LET V=10000
2540 LET W=10000
2550 LET X=10000
2560 LET Y=10000
2570 LET Z=10000
2580 LET A=10000
2590 LET B=10000
2600 LET C=10000
2610 LET D=10000
2620 LET E=10000
2630 LET F=10000
2640 LET G=10000
2650 LET H=10000
2660 LET I=10000
2670 LET J=10000
2680 LET K=10000
2690 LET L=10000
2700 LET M=10000
2710 LET N=10000
2720 LET O=10000
2730 LET P=10000
2740 LET Q=10000
2750 LET R=10000
2760 LET S=10000
2770 LET T=10000
2780 LET U=10000
2790 LET V=10000
2800 LET W=10000
2810 LET X=10000
2820 LET Y=10000
2830 LET Z=10000
2840 LET A=10000
2850 LET B=10000
2860 LET C=10000
2870 LET D=10000
2880 LET E=10000
2890 LET F=10000
2900 LET G=10000
2910 LET H=10000
2920 LET I=10000
2930 LET J=10000
2940 LET K=10000
2950 LET L=10000
2960 LET M=10000
2970 LET N=10000
2980 LET O=10000
2990 LET P=10000
3000 LET Q=10000
3010 LET R=10000
3020 LET S=10000
3030 LET T=10000
3040 LET U=10000
3050 LET V=10000
3060 LET W=10000
3070 LET X=10000
3080 LET Y=10000
3090 LET Z=10000
3100 LET A=10000
3110 LET B=10000
3120 LET C=10000
3130 LET D=10000
3140 LET E=10000
3150 LET F=10000
3160 LET G=10000
3170 LET H=10000
3180 LET I=10000
3190 LET J=10000
3200 LET K=10000
3210 LET L=10000
3220 LET M=10000
3230 LET N=100
```

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- A1 = Gallons of regular fuel in storage tank before refill for proposed system
- A2 = RVP of fuel before refill for proposed system - psi
- A3 = RVP of fuel before refill for standard system - psi
- B = Numbered day of year, beginning at maximum ambient temperature
- D5 = RVP difference, proposed-standard, before refill - psi
- D6 = RVP difference, proposed-standard, after refill - psi
- G1 = Gallons in max. sales volume tank (regular) at any time for proposed system
- G2 = Gallons (liquid) of recovered refueling vapors
- G3 = Gallons delivered to regular storage tank for proposed system
- G5 = Regular storage tank capacity for proposed system - gallons
- G6 = Regular storage tank empty level - gallons
- L1 = Gallons of regular fuel in storage tank at any time for standard system
- L2 = Regular storage tank capacity for standard system - gallons
- L3 = Gallons delivered to regular storage tank for standard system
- R1 = RVP of regular fuel at any time for standard system storage tank - psi
- S1 = Total station sales - gallons/day
- S2 = Regular sales - gallons/day
- T1 = Maximum dispensed fuel temperature - °F
- T2 = Minimum dispensed fuel temperature - °F
- T3 = Dispensed fuel temperature at any time - °F
- T4 = Maximum displaced vapor temperature - °F
- T5 = Minimum displaced vapor temperature - °F
- T6 = Displaced vapor temperature at any time - °F
- V1 = RVP of regular fuel at any time for proposed system storage tank - psi
- V2 = RVP of recovered refueling vapors - psi
- V3 = RVP of fuel delivered to station - psi

FIGURE C-7

STORAGE TANK RVP EQUILIBRIUM

STORAGE TANK RVP EQUIPMENT

Figure 8A shows a 6,000 gallon underground storage tank starting at an RVP of 9 psi. Fuel is dispensed from this tank until 3952 gallons of Regular have been sold. At this point, the vapors collected from the refueled vehicles for a total sales of 5200 gallons are pumped back into the underground regular storage tank. This occurs at the end of the first cycle and boosts the RVP to position 1, indicated on Figure 8A. The tank is then refueled to position 2, indicated on Figure 8A. The tank is then refueled to position 2. The change in gallon level with 9 psi fuel, which lowers the RVP to position 2. The change from the initial condition at 1 is indicated at AB for boost and from 1 to 2 as AD for dilution. This process is repeated several times until equilibrium is established.

The same conditions, but with a 9.15 psi RVP starting point, are shown on Figure 88. Note that the boost again increases the RVP but the dilution

effect lowers the tank to the same equilibrium point as shown in Figure 8b. The boost must be equal to ΔB . The in order for equilibrium to be established, ΔB must be equal to ΔB . The mechanics of this problem can be better understood if we plot the ΔB and ΔD associated with cycle 1 versus the RVP at position 1 for both starting conditions. Proceeding from 1 through 9 in this manner, we can generate the curves. Indicated on Figure 8c it can be seen that the boost curve is very flat. This says that we get approximately the same boost whether we start with a 5.0 or a 9.15 psi fuel. However, the dilution curve is rising very rapidly. This says that as the storage tank RVP departs from the refill RVP, the dilution becomes more significant. For example, when the storage tank is at 9 psi, the dilution effect is 0 since we are adding 9 psi fuel. The effect must increase from here.

The intersection of the two curves is the point where the ΔB and ΔD are equal and the indicated RVP will be the maximum operating point of the tank. When the storage tank RVP is below the indicated equilibrium point, the dilution effect is weak and the RVP will build until equilibrium is established. When the RVP is above the equilibrium point, the dilution effect is strong and the RVP will decrease to the equilibrium point. Thus, equilibrium will be established at an RVP 0.17 psi higher than the supplied fuel.

These results were obtained using hand calculations and graphical solutions. The 9.17 operating point agrees very favorably with the 9.169 answer derived from the time-sharing computer program.

FIGURE C-8

APPENDIX D ONBOARD REFUELING EMISSION CONTROL

Introduction

This Appendix covers experimental and design work performed within General Motors Corporation to evaluate the requirements of an onboard refueling emission control system. The basic approach was to establish the modifications required to the present production evaporative emission control system and to isolate the problem areas which would require more development.

Expansion of Production System

General Motors has evaluated the simplest possible expansion of a production evaporative control system to accommodate refueling vapor emissions. As shown in the Schematic of Figure D-1, this approach combined three additional charcoal canisters along with the production unit, thus multiplying the vapor adsorption capacity by a factor of four. It is well to point out that the canister purge valve shown in that schematic is the most sophisticated method currently applied to GM production cars. The necessary modification to the tank filler neck to add a large refueling vent is shown in the photograph of Figure D-2. The solenoid valve, apparent in that photograph, is an experimental expedient to shut off the refueling vent during vehicle operation so that the normal venting functions of the production evaporative control system are not impaired. The functions of that valve in a developed design would be handled by different hardware as will be discussed later. The engine compartment installation of the additional three canisters is shown in the photograph of Figure D-3.

The following test data illustrate that this experimental system was successful in storing a majority of the emissions from what might be considered a representative refueling condition. The tests involved installation of 19.5 gallons of 9 psi RVP fuel with a tank residual of 6.0 gallons. The dispensed fuel temperature was 70°F and the tank residual fuel temperature was 100°F. The target values for these temperatures were 82°F for the dispensed fuel based on the average summer measurements by Scott (see Reference 1 of the main body of this paper), and approximately 95°F for the residual fuel temperature to represent a 10°F rise over the peak ambient on an 85°F day.

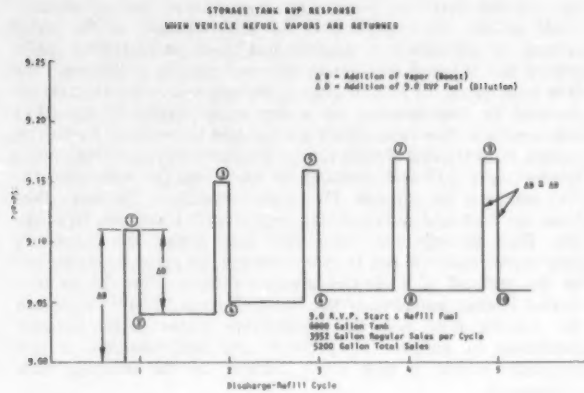


FIGURE C-8A

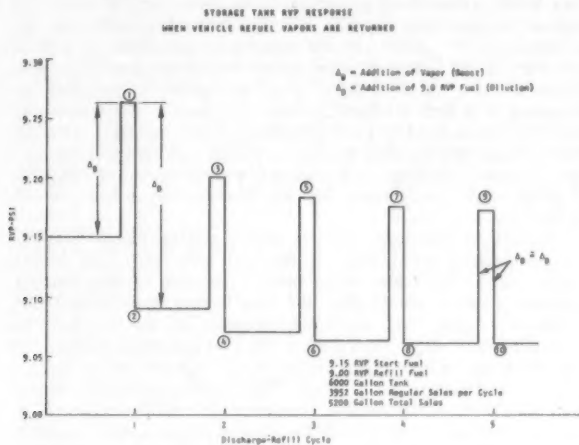


FIGURE C-8B

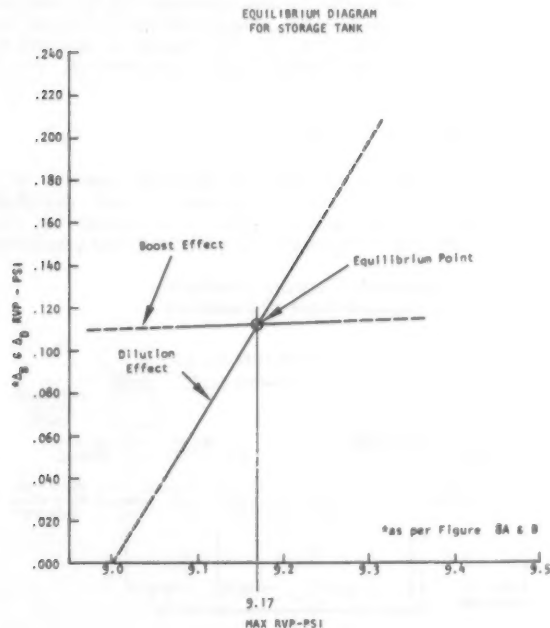


FIGURE C-8C

	Grams	Grams/Gallon
Weight Increase, "Refueling Canisters"	80.5	4.13
Weight Increase, "Production Canisters"	11.5	0.59
Total to Canisters	92.5	4.72
Loss to SHED*	9.3	0.48
Total	101.3	5.20

It is interesting that the foregoing data show approximately 90% control of refueling emissions with the experimental hardware and test procedures used.

Exhaust emission tests were performed to determine the amount of interaction on exhaust emissions which might be expected from the air/fuel ratio enrichment of the stored refueling vapors. The test data tabulated below indicate over 30% increase in carbon monoxide emissions. In all fairness, this value probably represents a maximum since the test comparison involved saturated charcoal canisters versus completely purged charcoal canisters.

*See SAE Recommended Practice J-171 or Reference 1 for a description of the SHED evaporative measurement technique.

	1975 EPA Test grams/mile		
	HC	CO	NO _x
Exhaust Emissions, Saturated Canisters	1.4	47	2.5
Exhaust Emissions, Purged Canisters	1.6	35	1.6
Interaction	-0.2	+12	-0.9

Exhaust Emission Interaction Problem

It is suggested by the foregoing test data, that onboard control of refueling emissions must be especially concerned with the effect of the eventual engine consumption of the refueling vapors. Without such attention, the net effect of onboard refueling emission control, when combined with depreciated exhaust emission control, could be an increase in overall vehicle emissions, i.e., increased exhaust emissions might offset the reduction in refueling emissions. The canister purge systems which have been developed to consume vehicle evaporative emissions with minimum exhaust interaction cannot be expected to handle the additional burden of stored refueling vapors—which can be upward of four times the quantity handled by the production evaporative control system.

To properly define the exhaust emission interaction of a refueling control system presents difficulty. In the case of vehicle evaporative emission control, a use cycle is defined by a single day. The conditions that affect evaporative emissions, such as ambient temperature, go through a complete cycle in a 24-hour period. Consequently, the true net effect on vehicle emissions from the evaporative control system and the associated exhaust emissions from the same vehicle must consider a complete day's use, i.e., one must consider the sum of the exhaust and evaporative emissions from all of the vehicle trips taken during a 24-hour period as well as the evaporative emissions which occur during vehicle parked periods as a result of hot soak and ambient diurnal heating.

In the case of the refueling emissions, on the other hand, the use cycle will in general involve several days. The precise manner in which the net effect of a control system on the total emissions associated with a vehicle should be evaluated is much more complex. One might visualize, for example, that a single test sequence to determine actual net emission effects might involve a number of regulatory evaporative and exhaust trip test sequences sufficient to consume a complete tank of fuel with a repeat of such a sequence to establish a base condition without the refueling control system.

The obvious solution to this dilemma is to provide a canister purge device which will control the secondary fuel input into the engine irrespective of the canister size or its loading. Figure D-4 shows such a "vapor carburetor" invented by a GM engineer. This device is designed to add the necessary air to the canister purge stream to maintain a relatively constant secondary air/fuel ratio through the medium of an electrically heated, catalytically-coated wire. The catalytic wire was used to sense both the presence and quantity of fuel vapors in the purge system.

A substantial amount of testing of a prototype showed that it did operate qualitatively as desired to control engine air/fuel ratio. However, its control was not sufficiently precise to eliminate the effects of evaporative control system interaction on exhaust emissions. Although no cost information is available on this device, it is apparent that additional cost and sophistication would be necessary to provide the desired precision of air/fuel ratio control. That satisfactory development of a secondary carburetion concept represents a formidable task is illustrated by the fact that engine carburetors consume more research and development than any other component in an automotive propulsion system.

Additional Hardware Required

In addition to the "vapor carburetor" discussed above, there are other necessary features which would have to be added to the present vehicle evaporative control system to adequately handle refueling emissions. First, the expansion of the charcoal capacity to at least four times the present quantity appears necessary. (It should

be conceded here that a very large expansion in charcoal quantity could reduce the requirements for sophistication of the purge system, or conversely a super-sophisticated purge system might reduce the required increase in charcoal capacity.) Secondly, the flow rates which the present evaporative emission control system are designed to accommodate are a very small fraction of the 10-15 gallon/minute flow rates which are required for venting of refueling vapors. Most General Motors current production evaporative control systems use a .055 inch orifice in the vapor vent line connecting the fuel tank and the canister. This orifice modulates the vapor flow from the tank and assists in the vapor/liquid separation function. The flow through the vapor vent line during the regulatory evaporative emission test is approximately .09 gpm—as determined by the method of Wade (see previous footnote) for the on-hour diurnal heating sequence of the fuel tank from 60-84°F. Although the real-life flow may be considerably higher under extreme conditions of ambient temperature and fuel volatility, it will obviously remain a very small fraction of the refueling flow requirement.

Consequently, refueling control onboard the vehicle requires a larger vent line to the vapor storage canisters than the current system. Initial estimates for this vent system indicated a 3/4" pipe size. While system development work has shown the 3/4" size to be somewhat larger than required, it is clear that a dual venting system is necessary to provide for the refueling requirements as well as retention of the functions of the vehicle evaporative control system. Figure D-5 shows a clever design by a GM engineer for providing the necessary dual tank venting functions. The large refueling vent line is shown to be closed by a specially designed two-seat filler cap at all times except during refueling. Thus, the large tank vent line provides the necessary refueling flow capacity without compromising the required flow modulation for the vehicle evaporative control system.

Present production evaporative control systems include a safety pressure-vacuum relief valve in the tank filler cap. This assures against structural damage to the tank in the event of some unusual occurrence which would close the tank venting path through the charcoal canister, (e.g., mechanical pinching of the vent line) or extreme conditions of temperature and fuel volatility. Addition of the refueling control to the present system would not necessarily affect that hardware or function. The refueling system, however, imposes a new safety venting requirement in that the highest flow rate to the vent system must be accommodated during refueling when the filler cap is removed. It would consequently be necessary to provide a high flow capacity safety pressure relief valve in the larger diameter vent pipe or the tank itself.

Finally, it is well to point out that experience with the described experimental hardware has shown some problems with liquid fuel entry into the refueling vent line. This suggests another area of development which could ultimately require additional hardware.

Complete Onboard System

Figure D-6 shows the previously described elements of a practical onboard refueling emission control assembled schematically into a complete system. A comparison of this schematic with that of Figure D-7 for a typical current production

**Schematic Diagram - Refueling
Emissions Control Canisters**

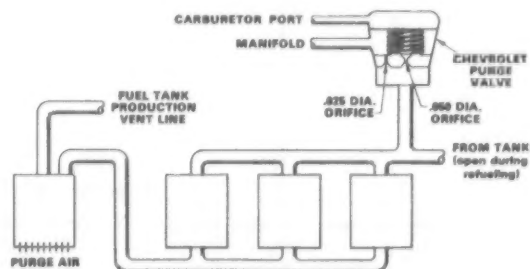
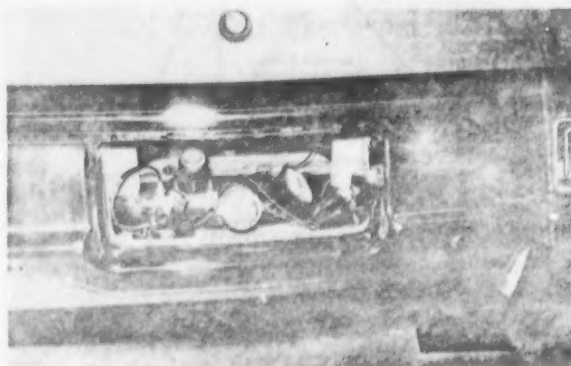


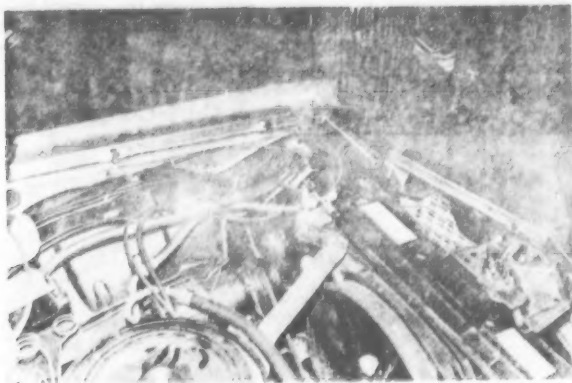
FIGURE D-1

evaporative emission control system, illustrates the substantial additional sophistication required for the refueling emission control. While a complete prototype has not been built by General Motors, our present experience suggests that such a system could be successfully developed, although in all probability at substantial increase in cost over present evaporative control hardware. In addition, it should be pointed out that onboard control would still require modification to service station nozzles to effect the necessary seal at the refueling interface.



VENTING HARDWARE FOR EXPERIMENTAL ON-BOARD
REFUELING EMISSION CONTROL SYSTEM

FIGURE D-2



CHARCOAL CANISTER INSTALLATION FOR EXPERIMENTAL
ON-BOARD REFUELING EMISSION CONTROL SYSTEM

FIGURE D-3

Purge Air-Fuel Ratio Controller

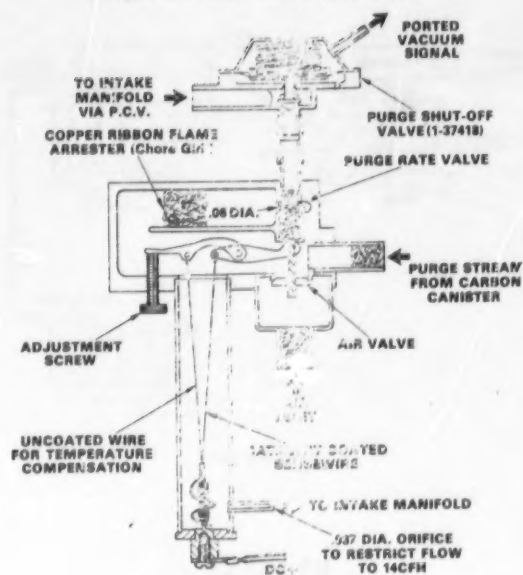


FIGURE D-4

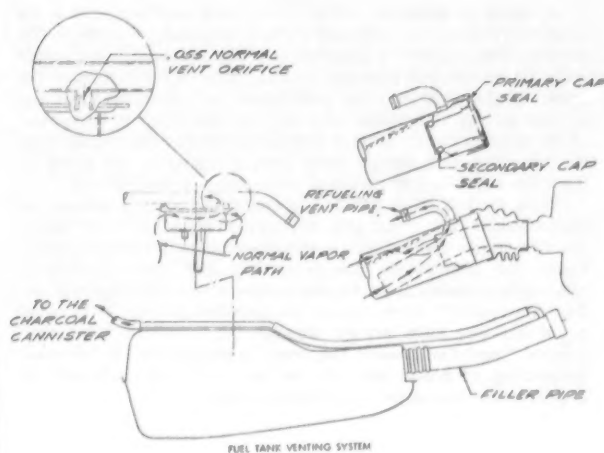


FIGURE D-5

On-board Refueling Emission Control Schematic

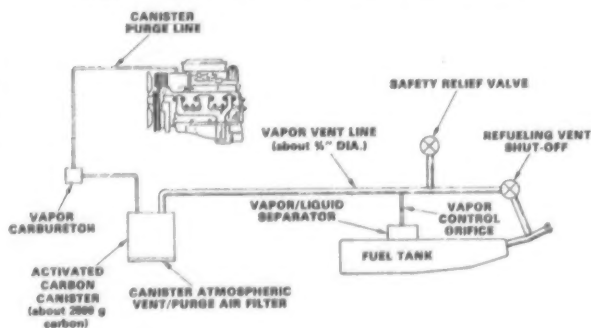


FIGURE D-6

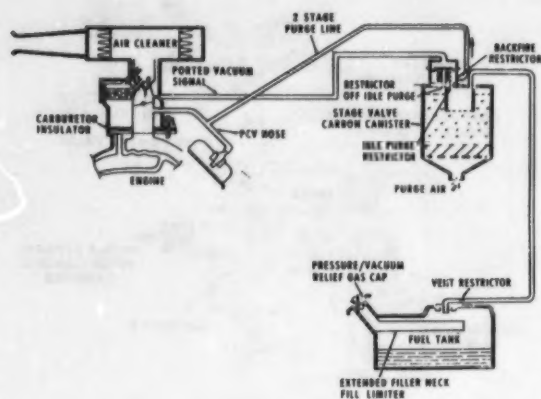


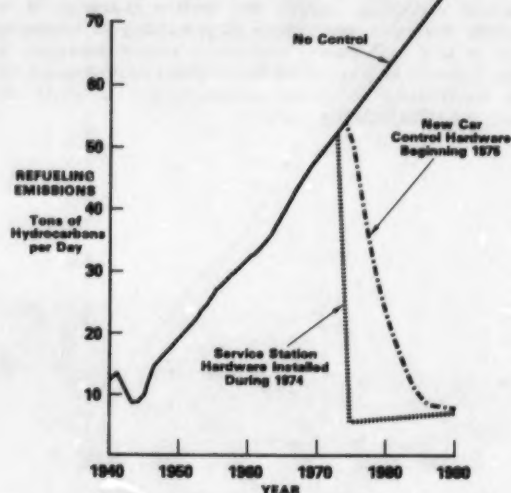
FIGURE D-7

APPENDIX E EFFECT OF REFUELING EMISSION CONTROL IN LOS ANGELES

In order to assess the effect of refueling emission control on total emissions to the atmosphere, it is necessary to consider the calendar time variable. Consumption related parameters associated with the automobile generally increase with calendar time as the result of the increasing car population and generally increasing mileage per car. In addition, any contemplated program for control of an emission source through new car hardware must consider that its full effect will require more than a decade as the result of retention in the car population of older, uncontrolled vehicles.

Since the Los Angeles Basin is the area most severely affected by photochemical smog, that area was selected to assess the effects of the two major approaches to vehicle refueling emission control. Figure E-1 displays the computed total daily tons of refueling hydrocarbon emissions to the atmosphere of the Los Angeles Basin. The "no control" curve reflects the projected increase in both car population and miles per car through the year 1990. The curve labelled "New Car Control Hardware" comprehends the historical distribution of model years in the total car population and the disproportionately higher use of newer models.

Los Angeles Basin Automotive Refueling Emissions



NOTE 1: Average refueling emission of 5.3 g/gal. assumed per CAPE-8
NOTE 2: 90% control of refueling emissions assumed by both car & station hardware

FIGURE E-1

In both the case of the "New Car Control" and the "Service Station Hardware" curves, an assumption has been made that 90% control of refueling emissions would be achieved on a per car basis. This assumption is consistent with the data presented in Appendix D. As expected, the two alternative control methods achieve the same total 90% control levels by about the year 1990. In the interim period, however, the service station hardware approach affects the maximum control as quickly as service station hardware can be installed. Thus, while new car control hardware produces a dramatic rapid reduction in total refueling emissions, the service station hardware approach provides an almost immediate reduction to the minimum level. Service station control has the further advantage that it can be applied to the local area(s) requiring control without imposing unnecessary costs on other areas of the state. It should further be pointed out that the service station (SCRC) system outlined in Appendix B would not only impose the assumed 90% control on automobiles registered in the Los Angeles Basin, but would also impose that same control on every car being refueled in the Basin.

A COST-EFFECTIVENESS APPRAISAL OF ALTERNATE SYSTEMS FOR NO-LEAD SAFEGUARD AND REFUELING VAPOR CONTAINMENT¹

by
Bruce Simpson

REFUELING VAPOR CONTAINMENT

- I. The recent study for the Department of Commerce by the Panel on Automotive Fuels and Air Pollution² shows clearly that the contribution of unburned hydrocarbons to the atmosphere during refueling operations compared with the 1975 exhaust HC standards of 0.41 gr/mile, is rapidly becoming a significant portion of the total. The HC vapor emissions during vehicle refueling are estimated at .32 gr per mile. To simplify the calculations, station refueling vapor losses were assumed equal to vehicle refueling losses. The relationship between HC emissions from exhaust and HC emissions from refueling is shown on Figure 8.

Various concepts appear possible to appreciably reduce vapor losses during present refueling practices. Three of these are considered in the following discussion.

- II. Several tight-fill systems have been conceived to prevent escape to the atmosphere of gasoline vapors during refueling of vehicle fuel tanks and filling station bulk tanks. Each system has significant, but different vapor containment capabilities.

Present refueling practices (Figure 9) indicate those vapor sources to which controls may be applied. The extent of changes to either vehicles and/or filling stations which would be required varies widely with the system which would be implemented. The following alternatives were studied:

- A. Refueling-vapor containment within the vehicle (Figure 10, Alternate A) As shown, this concept amounts to a much modified evaporative emission control system. The major advantages and disadvantages of this arrangement would be:
 - Imposes major task for control of exhaust emissions (intake system must handle the stored vapors when the canister is purged).
 - Requires little modification to filling stations.
 - In itself, vehicle containment would not control vapor emissions during station bulk tank refueling.
 - Waste of natural resources since trapped vapors must be incinerated by the engine.
 - Cost and system complexity rule out retrofit; therefore control of older cars cannot be accomplished practically by this method.
- B. Containment of refueling vapors by the filling station can be achieved over at least two avenues. The implementation of this alternative was studied with two timing installation assumptions:
 1. Pro-rate installation of necessary equipment in proportion to the increase in numbers of "new" cars, Alternate B.
 2. Installation of all equipment at one time-necessary to permit control of the entire vehicle population of older as well as new vehicles, Alternate C.

Applicable in either case is the "equal-volume exchange concept" shown on Figure 11, wherein the vapor from the tank being filled is transferred to the tank from which the fuel is being taken. Some of the changes needed to implement this concept are the following:

- a. One concept of tight-fill embodying a "standard" concentric tube nozzle (inner .81" O.D. tube for no-lead gasoline pumps, outer tube for vapor return) and a matching new-design vehicle filler neck is shown on Figure 12. This would apply to new vehicles.
- b. For cars on the road not equipped with the new style filler neck, some type of adapter would be required. One type of filler neck adapter for older cars is shown in Figure 13 (inner 1.06" O.D. tube would be used for leaded gasoline pumps, outer tube would be same diameter as for no-lead pumps). This would provide immediate control of refueling vapors from "older" vehicles. However, since there are many different sizes of filler pipes on past model cars of all makes, a multiplicity of adapters would be required at each filling station and would be impractical. The use of adapters would be difficult, if not impossible for police. The filling station attendant would have little incentive to use the correct adapter or any other system which complicates his job. This area deserves further study to determine if adapting tight-fill to past models is practical.
- c. Control of underground tank breathing and refueling vapors should be easily attainable (vent pipes are shown in Figure 11 with purgeable charcoal canisters which would be serviced periodically.) It is our understanding that Los Angeles County has had a rule requiring these controls for some time.
- d. Maintenance of the system, involving relatively few permanent installations, would be more effective than maintenance of systems on millions of vehicles.

III. Consumer costs for various tight-fill proposals.

- A. Vapor Containment within the vehicle-Alternate A
 1. Cost estimate per vehicle approximately \$17.35. (assumes use of positive-closure restrictor).
 2. Station costs for matching nozzles \$2.25 per no-lead nozzle. (See Figure 14 for car and total costs, by year of implementation.)
- B. Vapor Containment by Station (installations pro-rated for new vehicles only)-Alternate B
 1. Cost per vehicle \$1.60 (assumes use of positive closure restrictor).
 2. Cost per filling station: Initial cost slightly over \$800 is estimated-additional costs approximately \$675 per year. Cumulative cost estimates are shown on Figure 15.
- C. Vapor Containment by Station (All equipment installed first year of implementation.)-Alternate C
 1. Cost per new vehicle, \$1.60 (assumes use of positive closure restrictor).
 2. Cost per filling station: Approximate initial cost \$4600 for concrete, hardware, older car neck adapters and additional maintenance. Annual costs thereafter would probably average \$125/year. Cumulative costs are shown on Figure 16.

¹From a presentation prepared for the Environmental Protection Agency by Ford Motor Company, Dearborn, Michigan, October 28, 1971. References to Figure Numbers remain as they were originally.

²Report of Panel on Automotive Fuels and Air Pollution for U.S. Dept. of Commerce, March 1971.

IV. Cost Effectiveness

- A. Cumulative estimated costs of tight-fill gasoline vapor containment system are compared on Figure 17.
- B. Gallons of gasoline not emitted to the atmosphere for the three alternate systems are graphed on Figure 18.
- C. Costs per gallon of gasoline not emitted to the atmosphere are compared on Figure 19.
- D. Cumulative estimated costs per gallon vs. gallons of gasoline not emitted are compared on Figure 20.
- E. Costs of exhaust HC emission control are compared with costs of gasoline refueling vapor control on Figure 21. \$490 is estimated to effect the reduction of all exhaust pollutants (CO and NO_x as well as HC) from 1972 to 1975 standards (3.4 gm/mi to 0.46 gm/mi HC). However, it is quite difficult to determine what portion of that cost should be allocated for control of HC alone. Even if the \$490 was halved, the cost effectiveness analysis would still favor control of refueling vapor emissions over exhaust HC emissions on the basis of cost per pound controlled.

V. Timing Considerations

- A. Vehicle Design, test and production-timing requirements (Figure 22).
- B. Filling station equipment design test and installation requirements (Figure 22).

VI. Conclusions

- A. Hydrocarbon vapors of approximately 0.32 gm/mile from vehicle refueling represent very significant amounts when compared with 1975 exhaust emission standards, and therefore tight-fill gasoline vapor containment systems would appear to be an essential part of the total HC emission control program.
- B. The cost of preventing HC emissions from refueling vapor losses is about 1/15th of the cost of reducing the same amount of emissions by reducing vehicle exhaust emissions from 1972 to 1975 levels.
- C. Practical solutions seem technically feasible to control filling station and new vehicle refueling vapor losses, but a practical solution for older cars is not evident.
- D. Virtually complete control of station refueling vapor losses and both new and older car refueling vapor emissions is the most cost-effective approach (assuming that a practical solution could be found for handling older cars).
 1. It provides the lowest cumulative consumer cost after 9 years (Figure 17).
 2. It provides the greatest reduction of refueling vapors emitted to atmosphere (Figures 18 and 20).
- E. Only slightly less cost-effective than concept C which provides complete control of "all" refueling losses is concept B, which provides control of station and pro-rata control of new car refueling losses.
- F. The timing for vapor containment systems is estimated to require 42 months because the state of the art is not as well known as that of no-lead control systems. Due to the substantial gain that can be obtained, it would seem imperative that suitable standards be established to implement control of refueling losses at an early date.
- G. The design of an optimum system for accomplishing refueling vapor containment, and its timely implementation, will require concentrated government and industry effort. Appendix A indicates some actions which may be appropriate.

APPENDIX A

Members of the several industries affected by the problems involved in providing no-lead safeguards and refueling loss containment *cannot* unilaterally solve those problems. Implementation action by an appropriate, recognized coordinating

activity is seen as necessary to bring together all the disciplines required to address these complex and inter-related tasks on a timely basis.

Possible actions might include—

- I. Government review and promulgation of standards after appropriate rule making procedures which would invite comments from affected entities such as:
 - A. Auto industry, including foreign manufacturers
 - B. Petroleum industry
 - C. Station equipment suppliers, and
 - D. Associations of station owners and operators.

- II. Explore alternate innovative methods to perform the refueling operation. A study may show that the safest and most efficient methods of assuring that a specific fuel only is dispensed without vapor loss need not be based on simple modifications to present refueling equipment. For example, the next generation dispensing system could involve an "air-tight" quick-connect coupling with remote pump switch and automatic pressure-shut-off.

- A. Develop additional, lower-cost, more effective no-lead safeguard concepts.
- B. Develop additional, lower-cost, more effective refueling loss containment alternates.

- III. Initiation of test and analytical programs where necessary to obtain background data not available through other sources. More comprehensive information which would aid in the decision making process for no-lead safeguards include:

Permissible amount of alien fuel per fill attempt (half cup, one cup?) and how often before measurable, irreversible damage to the catalyst occurs.

More comprehensive information which would aid the decision making process for refueling vapor control includes:

- A. Confirmation of implementation costs for control by vehicle and by station so as to arrive at the most cost-effective solution.
- B. Lead content of vapor in fuel tanks containing leaded fuel.
- C. Line size to handle vapor displaced at 12 gal/min.
- D. Determine best method for vapor control entrapment and reuse or disposal of displaced vapor. Potential systems could include:
 1. The simple exchange of volume of displaced vehicle tank vapor for the volume of fuel dispensed from the bulk tank.
 2. Separate vapor storage reservoir under pressure.
 3. Vapor adsorption by charcoal with periodic vapor purge and recovery.
 4. Use of refrigeration and liquefaction.
 5. Catalytic conversion of vapors to harmless effluent.

IV. Ford Position

- A. Ford pledges to cooperate where legally possible in any effort chosen by EPA or other government agencies to complete the projects by 1974 model introduction. For example, the Company could commit
 1. Experienced members from its design staff.
 2. Extensive testing facilities.
- B. Through its national advertising, press releases and other channels of communication, the Company will contribute to the education of vehicle owners and station operators regarding their individual responsibilities.

LEGAL FOOTNOTE

The functions that would be performed by no-lead safeguards and refueling vapor containment systems clearly seem to be within the general intent of the Clean Air Amendments of 1970. Authority

to act on these items may be found in at least two sections of the Clean Air Amendments of 1970:

Section 211(c) (1) gives the Administrator the right to control or prohibit the sale of a fuel or fuel additive, and presumably gasoline pumps could be restricted so as to "control" the sale of leaded fuels.

Under Section 111, the Administrator could add gasoline filling stations to his list of "stationary sources," and thus allow regulatory controls to prevent or curtail refueling vapor losses.

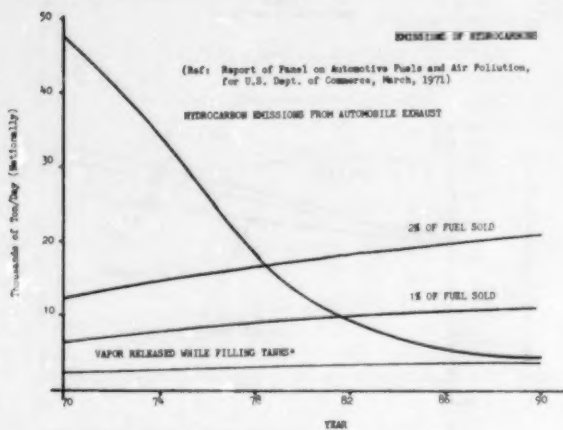


Figure 6

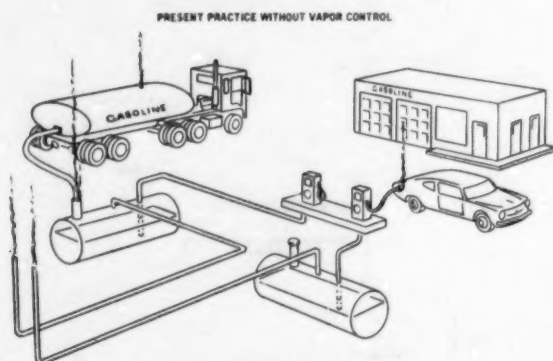


Figure 9

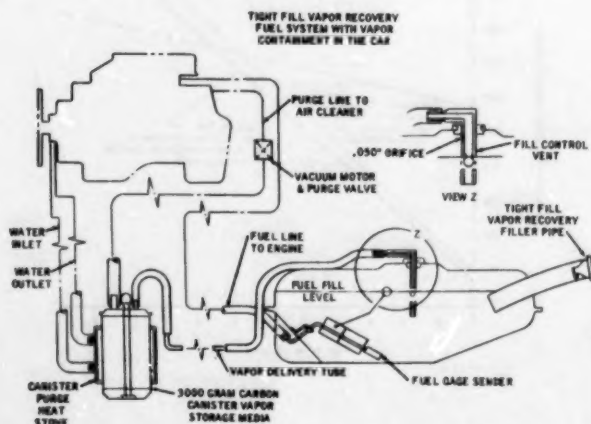


Figure 10

EQUAL VOLUME DISPLACEMENT & EXCHANGE

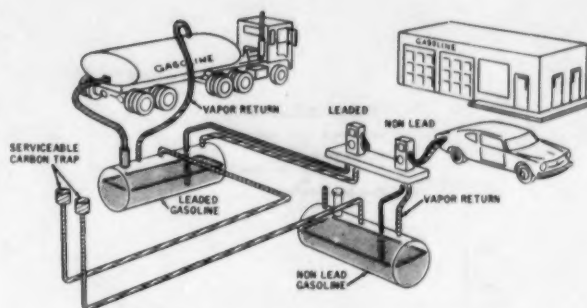


Figure 11

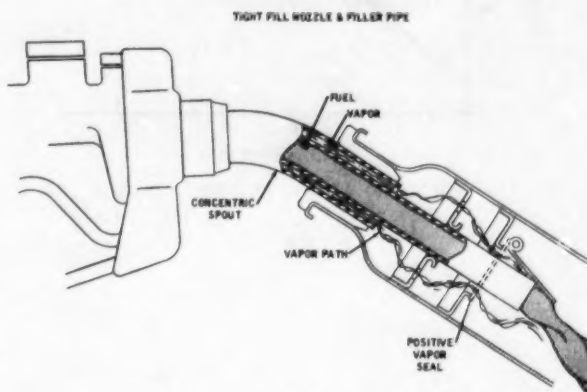


Figure 12

RETRO-FIT ADAPTER FOR PAST MODELS

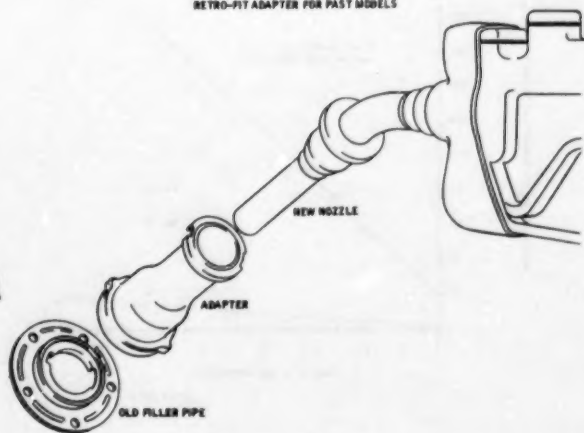


Figure 13

Figure 14

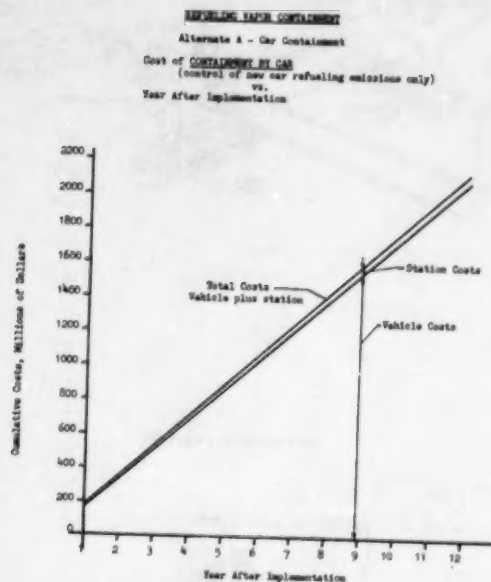


Figure 16

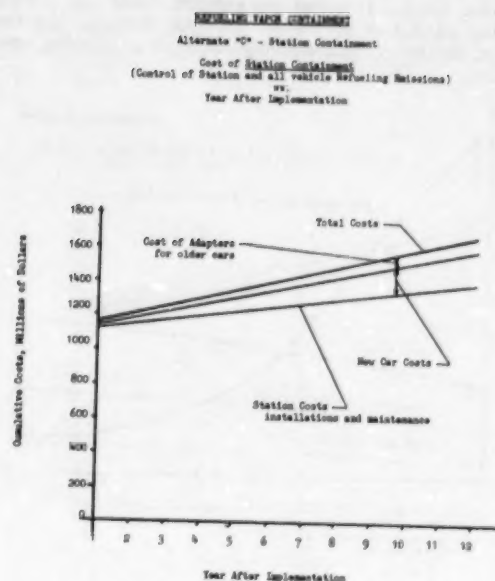


Figure 15

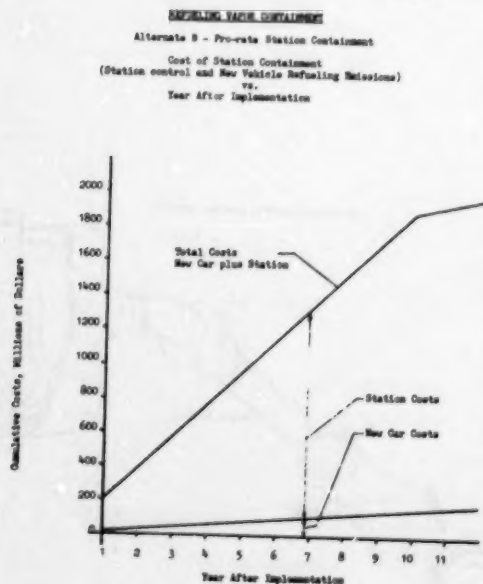
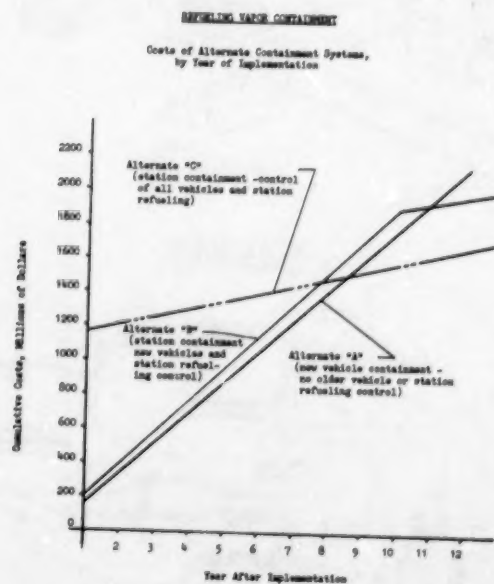
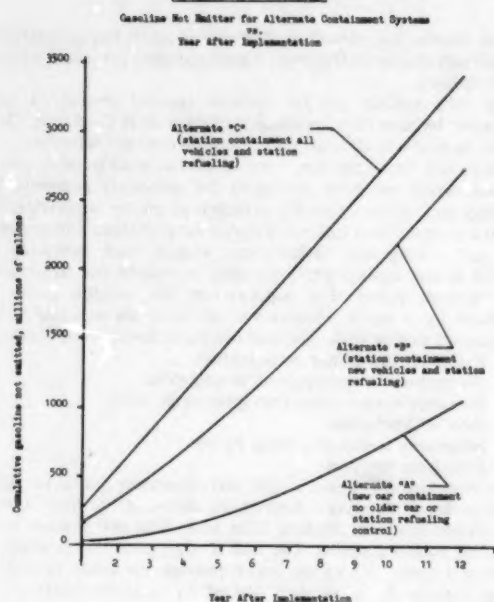


Figure 17



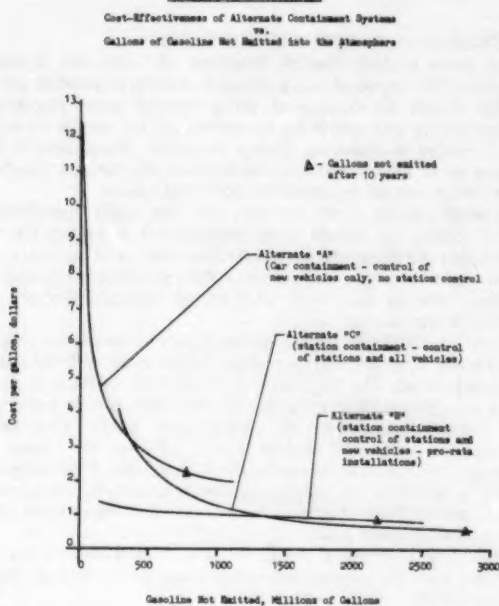
REFUELING VAPOR CONTAINMENT

Figure 18



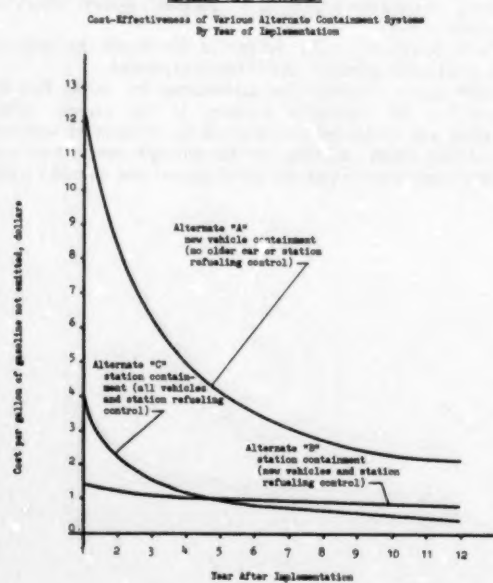
REFUELING VAPOR CONTAINMENT

Figure 20



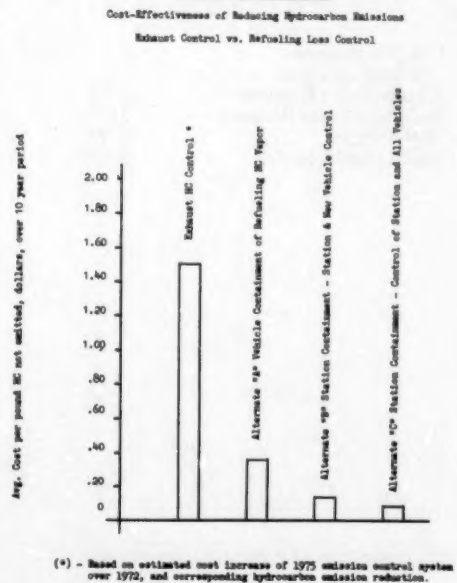
REFUELING VAPOR CONTAINMENT

Figure 19



REFUELING VAPOR CONTAINMENT

Figure 21



NEW EMISSION CONTROL EQUIPMENT

by
Jack L. Gockle

MR. CHAIRMAN, LADIES AND GENTLEMEN:

My name is Jack Gockle, President of Clean Air Research Company. The degree of vapor recovery control at gasoline service stations should be determined on a regional basis. Regulatory agencies should first decide on the amount of HC emission control that is needed to meet air quality standards. Then, they should examine all of the options available to attain the clean air standards at the lowest cost per ton removed from atmosphere.

In some regions of the country, only the highly cost-effective control options are needed to be implemented. In regions like the South Coast Air Basin, the cost to the consumer must be considered because each successive step toward 100% control becomes less cost effective. This is true with controls on vehicles, sewage, and electrical power plants.

There are two basic approaches to service station vapor control. The primary approach is vapor displacement only of both vehicle and storage tanks. The secondary approach is the addition of a unit that recovers vapors not controlled by the displacement technique. With today's population of vehicles and nozzle technology, displacement only will recover about 75% of the vapors. A secondary unit can recover nearly all of the balance if vacuum-assist is used to withdraw the vapors from the vehicle tank. The vacuum-assist is needed because nozzles do not seal on all vehicles and many vehicles have external vents.

Secondary recovery is useful for recovering diurnal losses and working losses, but its real value results from the recovery of vapors generated when vacuum assist is used.

In a regional evaluation of whether or not to use primary or primary and secondary control, the regulatory agencies should compare the cost effectiveness of the secondary control with other options for the control of photochemical smog. The primary control is extremely cost effective and probably will be used in any region requiring an oxidant reduction over that provided by new vehicle controls. In areas like Los Angeles where no degree of control will meet the standards, the following cost-effectiveness comparisons are of interest:

Cost Effectiveness \$/Year/Ton/Year	
Primary Vapor Recovery	\$ 36
Secondary Vapor Recovery	\$193
1974 Vehicles	\$593
Used Vehicle Retrofit	\$329

It is shown that secondary recovery is much less cost effective than primary recovery. However, it *does* compare favorably with the vehicle options.

The two vehicle control options selected provide a good comparison because they are being implemented in California. Other options, such as vehicle inspection, are even less cost effective.

Before my time runs out, I would like to quickly show you an approach which we have developed for secondary recovery. The secondary unit operates on the principle of on-site regeneration of activated carbon. Two carbon canisters are provided. Excess vapors from tank filling and vapors from storage tank breathing are captured in one canister while the other is available for regeneration by a vacuum pump. The vapors from the vacuum pump are condensed by a small refrigeration unit and are returned to the underground storage tank. The unit has the following advantages:

1. Relatively low power consumption
2. No pressure in underground storage tank
3. Recovers vapors rather than incinerates them
4. Over 95% effective
5. Adaptable to any size filling station
6. Relatively low cost

We have also developed a tight seal dispensing nozzle for filling vehicle tanks at the service stations. As shown in the slide, a seal is made on the inside of the tank filler neck. This seal is made by an expanding rubber annulus. The seal is contracted mechanically by actuating a lever. Vapors are drawn through the inside face of the sealing annulus by a vacuum created by a pump inside of the secondary unit previously described.

The nozzle features a positive relief valve for tank protection in the event that the automatic shut-off device fails to operate. A simple check valve is provided to shut off the vacuum-assist when the nozzle is holstered in the dispensing pump. The check valve opens by allowing a stainless steel ball to fall out of its seat when the nozzle is tilted for dispensing fuel. This check valve can be also used when the nozzle is part of a "balance" system where no vacuum-assist is used.

We have developed another version of this nozzle that prevents the flow of gasoline unless the inside seal is expanded.

I would like to conclude this presentation by stating that the application of the principles involved in the on-site carbon regeneration unit shows great promise in the recovery of vapors at bulk terminals. Units operating on this principle should have very low power requirements and the initial capital cost should be low.

VAPORTROL VAPOR RECOVERY SYSTEM

by
John E. Perry

The Vaporex developed Vapor Recovery System for service stations and wholesale dealer bulk plants satisfies the most severe pollution control requirements safely and with excellent cost effectiveness. Regulations pertaining to control of volatile organic compound storage and loading are presently scheduled for compliance from early 1974 through 1976.

The Vaportrol Model VS-1 Service Station Unit and the Model VB-1 Bulk Plant Unit are identical in concept; both use refrigeration to condense excess hydrocarbon vapors and cool the entire vapor phase to equilibrium pressure conditions. The process flow schematic shows how the system works.

All of the concepts used in the so-called balanced vapor return system are utilized in the application of the Vaportrol Unit. The refrigeration unit and blower merely improve the performance of a balanced system to yield nearly 100 percent containment of the captured vapors. The release of untreated hydrocarbon vapors can occur only during an emergency condition. Service evaluation tests in actual service station operations have demonstrated that through normal environmental conditions no untreated vapors escape from the Vaportrol System.

Condensation of hydrocarbon vapors may tend to shift the composition in the underground storage tanks towards a lean mixture, but resaturation has been observed to bring the components into equilibrium. Stored vapors are returned to the terminal each time product is delivered to the station. The ambient effects on the diurnal losses are greatly reduced in a closed system operating within the low pressure range of the Vaportrol System.

It is assumed that when the Vaportrol is placed in service that vapor return systems have been installed on all of the delivery

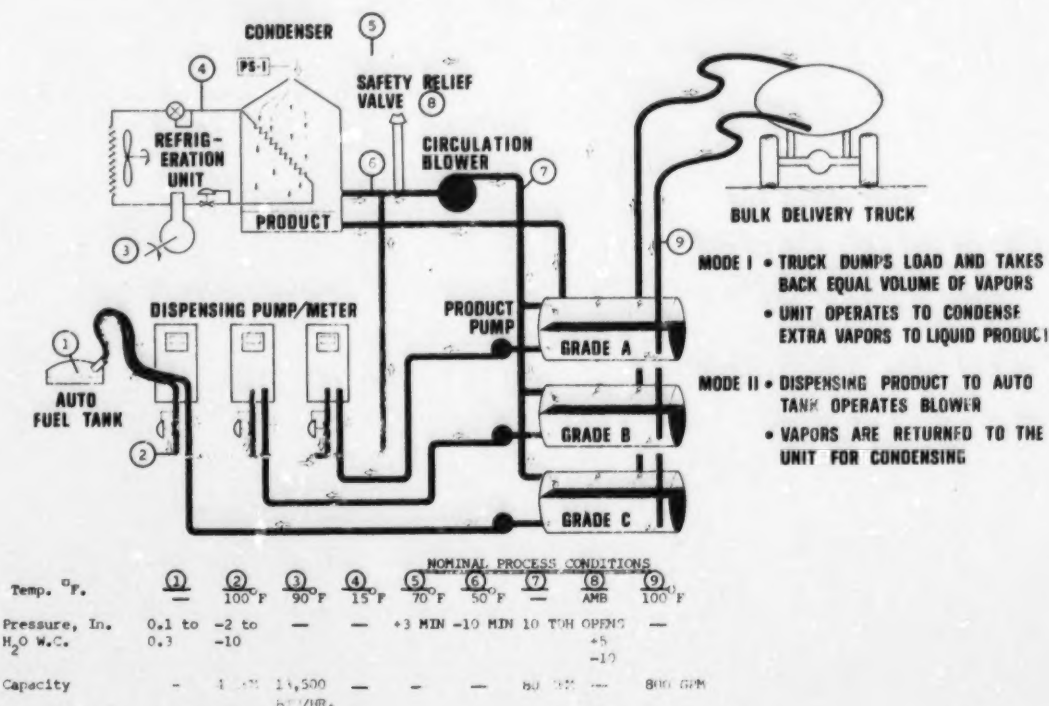
trucks/trailers. A "dry break" or self sealing quick disconnect on the vent of the product storage tank is part of this system. This piping allows an equivalent quantity of vapors to be returned to the delivery truck. For example, if 7,480 gallons were delivered, 7,480 gallons or 1,000 cubic feet of vapors would be returned. Also assumed was the availability of U.L. approved product dispensing nozzles and vapor return hoses.

When product (gasoline) is gravity delivered, excess vapors are generated approximately proportional to the difference in temperature between the supply and storage liquids. It is common to have 10-15% excess vapors generated during a "dump." In the previous example the excess would amount to about 100 cubic feet. Since the vent system is closed these additional vapors cause the pressure to rise.

At three inches of water pressure, the pressure switch PS-1 activates a timer control which "turns-on" the circulation blower and refrigeration blower. All of the vapors are caused to circulate across the condenser and return to the storage tanks. On each pass of the vapors through the condenser some hydrocarbon vapors are condensed to liquid product and the vapor stream is cooled about 20°F. Through this process of converting a large volume of gas into a small volume of liquid and reducing the bulk temperature of the vapor space, the pressure is reduced to an equilibrium condition below the switch point at PS-1. Two to four 15 minute cycles are required to reduce the pressure. Typically, the system will operate for less than one hour per "dump" and prevent any escape of HC vapors to the atmosphere.

Vapor collection at the auto tank is accomplished through a vacuum assisted displacement scheme; as product is delivered into

VAPORTROL FLOW SCHEMATIC



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the tank, vapors are directed through a modified dispensing nozzle and hose to a large area diaphragm valve which regulates the pressure on the tank and collection hose to plus 0.1 to 0.3 inches of water column. This valve is a Vaporex development which prevents the entire system from handling an explosive mixture. Since the vapor piping from the island is on the suction side of the blower, a minus 4.0 to 6.0 inches water pressure exists at the regulator when the blower is operating. Control of the blower in this mode is provided through the action of turning on the product dispenser.

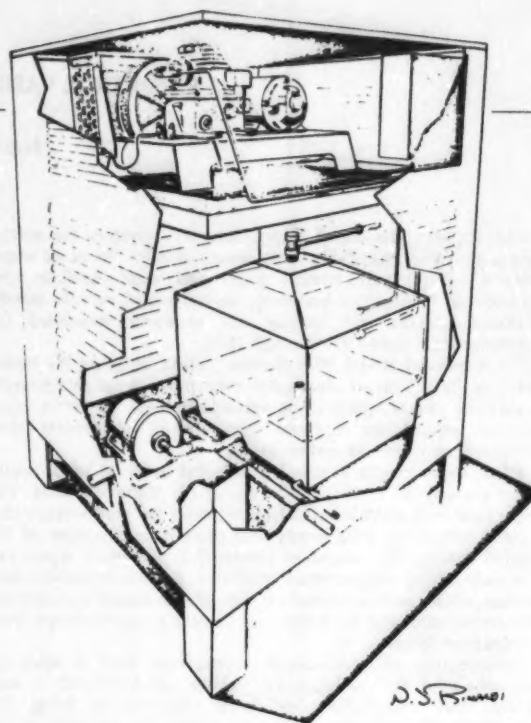
Since the system operates on a demand basis, the cost of power is greatly reduced compared to a continuously operating unit. For example, a 200,000 gallon per month station operating 25 days per month, twelve hours per day, would require an 8,000 gallon delivery on the average of every day of operation. During and shortly after delivery the refrigeration and blower would be turned on and process the excess pressure down to equilibrium conditions; this would require about 1.5 KW. To dispense 8,000 gallons per day the product pumps, and subsequently the blower, would have to run approximately four hours. This utility requirement would also equal approximately 1.5 KW. Therefore the total power consumption per day would be approximately 3 KW per day.

To recap the operation of the system:

1. During a dump or at any other time a positive pressure greater than three inches of water occurs, the blower and refrigeration system operate to reduce the pressure.
2. During product delivery to the auto, the blower operates to provide an adequate suction at the island to direct the vapors into the system. The "anti-air" suction valve prevents the dilution of the vapor with air.

The sketch depicts the standard service station unit; it is vertically oriented and requires a pad approximately three by four feet. The refrigeration unit located in the upper compartment utilizes weathertight electrical equipment while the blower and other controls in the lower compartment have Class I, Group D explosion-proof enclosures. Refrigeration maintenance is expected to be comparable to packaged chillers, which have a record of approximating home refrigerator reliability.

Units are now being produced for service evaluation testing by the major oil companies and others. The Vaporex approach and



execution are completely acceptable with regard to all fire and health safety codes, as well as traditional standards imposed by the petroleum and insurance industries.